Joint Planning and Development Office

NextGen Weather Plan

Version 2.0

October 29, 2010

Next Generation Air Transportation System
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Joint Planning and Development Office (JPDO)

Next Generation Air Transportation System (NextGen)

Weather Plan

Version 2.0

October 29, 2010

EXECUTIVE SUMMARY

The Next Generation Air Transportation System (NextGen) Weather Plan (the Plan) is a multi-agency plan that identifies roles and responsibilities for developing, delivering, operating, and incrementally improving a NextGen Weather Enterprise. It highlights the steps required to achieve an Initial Operational Capability (IOC) for both weather information and translation of weather into impacts that can be easily used by pilots, air traffic planners, dispatchers, and controllers. It highlights policies that must be addressed and research that must be accomplished to support a NextGen Weather Enterprise. It also presents opportunities for collaboration with other international aviation weather providers and air traffic systems.

According to Federal Aviation Administration (FAA) studies, significant growth in the demand for air traffic services is anticipated by 2025. To accommodate this growth, the FAA is planning on incrementally implementing new operational technologies and capabilities. Many of these new capabilities, such as Trajectory-Based Operations (TBO) and Super Density Operations, will require improved accuracy in weather information and improved access to net-centric weather information.

The information-sharing component of NextGen, known as Net-Centric Operations (NCO), relies on access to network-enabled information and provides a foundation for the timely and efficient exchange of weather information. A new weather information distribution architecture to promote Shared Situational Awareness (SSA) has been defined to leverage emerging NCO standards and constructs with existing weather collection and distribution architectures. This Architecture is called the NextGen Four-Dimensional (4-D) Weather Data Cube, and is referred to as the "4-D Wx Data Cube" within this document. The 4-D Wx Data Cube concept meets all NextGen weather goals and requirements, while allowing for the provision of current regulatory weather products. Additionally, it enhances weather information availability (e.g. weather observations, forecasts, probabilities, and space weather). Cross-agency, intra-agency, and commercial net-centric services will promote the access, sharing, and manipulation of weather information and data to better accommodate the needs of different user communities.

Led by the National Oceanic and Atmospheric Administration (NOAA) and the FAA, Federal agencies have been working together to define and validate the NextGen aviation user needs for weather information. Each agency brings unique needs, capabilities, understanding, and focus with regard to the current and historical role of weather information. Each Agency is also responsible for execution and regulatory areas (i.e., safety, training, procurement, reliability, maintainability, etc.). The Plan provides a science and technology roadmap to satisfy these needs, defines the multi-agency work plan, and describes the management structure required to support the operational capabilities planned for NextGen. It outlines the incremental approach that will be used to develop and deliver a NextGen Weather Enterprise as NextGen operational capabilities mature.

This plan identifies policy issues and governance required to enable the use of a NextGen Weather Enterprise. The Plan also establishes the approach for integrating weather information

into the Air Traffic Management (ATM) decision-making process through the use of enterprise services. This includes the emergence of the "common weather reference" as facilitated by the 4-D Wx Data Cube and its associated net-centric enterprise services. This reference provides weather consistency, reliability, and unique weather forecast uncertainty. The Plan describes the use of enterprise services to facilitate translation of weather information into weather constraints, and then further into weather impacts. Such translations will support integration of the derived impacts with a wide range of decision support tools (DST) that will provide information to aid ATM decision making. The effects of weather uncertainty will directly support weather impact risk mitigation strategies. Without operational acceptance and understanding of weather uncertainty, TBO will be compromised.

Finally, the Plan also describes the need for global harmonization of aviation weather information. According to the *NextGen Concept of Operations* (ConOps), this harmonization is achieved through the collaborative development and implementation of identified best practices in both standards and procedures. The Plan describes the strategy for developing International Civil Aviation Organization (ICAO) documents and FAA Air Traffic Organization (ATO) International Strategic Plans to facilitate the global interoperability of operations like Oceanic TBO, Cross-Polar Routes, and operations affected by volcanic ash and tropical storms.

The Plan, though not always specifically addressing industry and non-government end-users at this time, will include those stakeholders in forthcoming versions and revisions to the NextGen Weather Policy and other sections as appropriate. Industry and non-government end-users are critical to the success of net-centric weather information.

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1 INTRODUCTION

1.1 Problem Statement

Today's air transportation system is prone to weather disruptions causing flight delays and inefficiencies, with widespread impacts. For example, it has been estimated that weather delays account for 70 percent of the $41B annual cost of air traffic delays within the United States National Airspace System (NAS), or $28B annually[1]. Approximately two-thirds of these delays could potentially be avoidable through improved advance planning when adverse weather is predicted to occur. These delays and inefficiencies are manifested in such operational problems as:

- Multiple, inconsistent weather forecasts lead to a lack of agreement between Air Navigation Service Providers (ANSP) and users on the potential weather situation and its impact; non meteorologists are forced to make decision based on their own interpretations of weather information

- Daily plans of ANSPs and users are overly conservative in responding to anticipated weather, e.g. traffic management initiatives including ground delay programs, ground stops, reroutes, etc.

- Loss of terminal capacity as arrival and departure flows are dealt with tactically as weather develops

- Inefficient management of airport runway configuration due to lack of advanced information on wind shifts

- Loss of airport capacity due to lack of reliable information on when ceiling and visibility constraints will not longer be an issue

- Overburdening of sector controllers in dealing with pilot requests for assistance in tactical convection or turbulence avoidance, thus reducing sector capacity

- Accidents or incidents caused by lack of timely weather information that is tailored to the needs of each flight

While severe weather will likely continue to prevent airspace and airport access in the immediate vicinity of the event, the impact of many of these events could be reduced through improved weather observations and forecasts, better dissemination to all stakeholders, and more proactive ways of dealing with weather throughout the NAS. The current ATM system and supporting decision-making tools are primarily reactive to weather events and are ineffective in implementing the NextGen vision for mitigating the impact of weather on NAS operations.

[1] REDAC Weather-ATM Integration Working Group Report; Oct 3, 2007

In the current system, weather information is often separated from the ATM process, on both the FAA and user sides. In some cases, current ATM processes discount weather forecasts, claiming that the weather forecast is not accurate or that different forecasts are inconsistent. Currently, the FAA receives weather information from a collection of diverse, uncoordinated observation systems, forecast platforms, both government-provided and vendor-provided. Low confidence in forecasts (especially those beyond two hours) leads ANSP and users to make decisions that are too conservative, or to wait until the weather actually occurs before reacting. Also, the availability and interpretation of weather information differs among stakeholders (ATM, ATC, pilots, and dispatchers). Additionally, techniques and approaches to assess weather information to determine the user's unique potential operational impact vary among users. The effectiveness of the impact assessment and actions taken depends on the skill of the individual decision maker.

In general, ATM DST developed to date (to assist in flow planning, terminal operations, and en route operations) are not integrated with key weather information. For example, terminal flow metering tools are not aware of impending convective activity that could affect a key corner post, necessitating a manual reconfiguration of arrival traffic. This manual adjustment requires interpretation by the controller, who must manually integrate this information into traffic decisions based on his or her perception of the information presented. Thus, the lack of automated tools necessitates a cognitive, reactive, and inefficient weather-related decision-making process. Additionally, it requires meteorological competency on the part of decision makers during the times of greatest need for automated assistance. What results is a manual interpretation of potential weather impacts and perception based largely on experience to determine the "best weather data source."

In summary, the mitigation of weather's impact on NAS operations will require that NextGen address the following major needs:

- Provision of a consistent, accurate, and timely set of weather observations and forecasts that all decision makers can utilize and trust

- Translation of weather information sources into characterizations of potentially weather-constrained airspace; systems and users would deal with the constraint information with an understanding of how those constraints were derived

- An efficient, cost-effective dissemination capability that makes weather information available to all users. And, this infrastructure will enable proactive dissemination of changes to the weather situation to any requesting stakeholder to ensure up-to-date situational awareness

- Translation of potentially weather constrained airspace into weather impacts

- The integration of these weather impacts into ATM decision making. This includes development of new procedures for ANSP/user collaboration on dealing with weather situations. This also includes the direct integration of weather into ANSP and user DSTs

to inform alternatives analysis and strategy development for dealing with the evolving weather situation

- Weather information capabilities and ATM decision processes agile in dealing with changes to the weather situation at the earliest possible moment to minimize disruptions to users and workload on ANSPs.

These, therefore, are the challenges that the NextGen weather system, as defined in this plan, must address to ensure that NextGen objectives can be achieved.

1.2 Purpose of NextGen Weather Plan

Testimony before the House of Representatives Committee on Science and Technology Policy in 2008[2] indicated that a number of stakeholders expressed concerns about the usefulness of the JPDO's three planning documents (Concept of Operations, Enterprise Architecture, and Integrated Work Plan). It also indicated that the FAA's *NextGen Implementation Plan* lacked the information that industry participants need for successful planning.

This plan addresses stakeholders' desire for planning documents that provide a high-level view of NextGen benefits, and also specific details, such as a catalog of critical needs, clearly defined and prioritized intermediate objectives, and a structured plan for achieving tangible results. It summarizes the multi-agency activities that must be accomplished to build and produce network-enabled NextGen weather information, establish secure information exchange standards, ensure access and distribution of the weather information, and establishes an approach to facilitate the integration of weather information into NextGen operations. Because this is a high-level plan, the details on the activities required to support a NextGen Weather Enterprise are described in more detail in the annexes to this plan.

This plan also identifies policy issues and governance required to enable the use of a NextGen Weather Enterprise. It further provides a science and technology roadmap to meet aviation weather needs and seeks to define work, cost profiles, timelines, and critical milestones to achieve operational status for the 4-D Wx Data Cube. This plan was developed in coordination with NextGen industry partners and provides industry a means of determining how their business case fits into a NextGen Weather Enterprise based on the Government's plan. This plan also serves to create synergy between the various NextGen agency programs and plans as it supports synchronization of the agency activities required to develop an operational NextGen Weather Enterprise.

1.3 NextGen Vision

A multi-agency, synchronized plan to achieve solutions to the problems highlighted in section 1.1 is needed. As articulated in the NextGen vision, the solution must enable decision makers to

[2] House of Representatives Committee on Science and Technology Policy, September 11, 2008, "NextGen – Status of Key Issues Associated with the Transition to NextGen"

identify areas where aircraft can fly safely, with weather assimilated into the decision-making process in order to improve NAS efficiency during constraining weather events. The Plan provides the initial scope and implementation roadmap to address the requirements for achieving the NextGen weather vision. It also addresses agency roles and responsibilities.

The Plan is a first step toward meeting documentation requirements developed by the JPDO and the FAA. These documents include the *Four-Dimensional Weather Functional Requirements for NextGen Air Traffic Management v0.1*, released in January 2008, and the planned release of updated Version 0.2, and the *NextGen Four-Dimensional Weather Data Cube Single Authoritative Source (4-D Wx SAS) Functional Performance Requirements*. It is important to note that these JPDO and FAA requirements are focused on the NextGen end state (2025) and not Initial Operating Capability (IOC).

1.4 NextGen Key Capabilities

There are eight capabilities to achieve NextGen goals, which are outlined in the *NextGen Concept of Operations* (ConOps), Version 3.0 (December 2009). The Plan explicitly addresses two of these capabilities:

- **Net-Centric Information Sharing**
  The information-sharing component of NextGen is network-enabled information access known as Net-Centric Operations (NCO). Its features allow NextGen to adapt to growing operations, as well as shifts in demand, making NextGen a scalable system. NCO also provides the foundation for robust, efficient, secure, and timely transport of information to and from a broad community of users and individual subscribers, as well as for the information exchange between machines and systems, and agencies. The resulting system minimizes duplication, achieves integration, and facilitates the concepts of distributed decision making by ensuring that all decision elements have exactly the same information upon which to base a decision, independent of when or where the decision is made.

- **Weather Assimilated into Decision Making**
  The decision-making component of NextGen includes weather assimilated into decision making. Integrating weather surveillance data from ground stations, air vehicles, and space-based platforms will provide real-time weather situational awareness. Aircraft will have the ability to observe and share weather information. Probabilistic forecasts will be provided to determine likely weather impacts for use in strategic planning. SSA services will offer a suite of tools and information designed to provide NextGen participants with real-time aeronautical and geospatial information that is communicated and interpreted between machines to facilitate collaborative decision making (CDM) between users. A reliable, common weather picture integrated with a wide range of user DSTs will provide information and automatic updates to aide optimal air transportation decision making.

1.5 Weather Support of Key NextGen Characteristics

Weather will support three key NextGen characteristics identified in the *NextGen ConOps*: Distributed Decision Making, Global Harmonization, and Automated and Human Decision Making.

- **Distributed Decision Making**
  Network-enabled weather information will support distributed decision making in NextGen, while providing an awareness of system-wide implications. Stakeholder decisions are supported by access to a rich information exchange environment and a transformed collaborative decision-making process that allows broad access to information by all parties (whether airborne or on the ground) while recognizing privacy and security constraints. Information is timely, relevant, accurate, quality assured, and within established security procedures. Information must also be "horizontally consistent." That is, consistent across all systems at the same time. Decision makers have the ability to request information when they need it, publish information as appropriate, and use subscription services to automatically receive desired information. This information environment enables more timely access to information and increased situational awareness, while providing consistency of information among decision makers. Because decision makers have more information about relevant issues, decisions can be made more quickly, required lead times for implementation can be reduced, responses can be more specific, and solutions can be more flexible to change.

- **Global Harmonization**
  According to the *NextGen ConOps*, the ATM system is globally harmonized through collaborative development and implementation of identified best practices in both standards and procedures. The goal of global harmonization is to establish operational standards and multilateral agreements to coordinate planning and implementation of NextGen weather-related transformations in technology and procedures for the delivery of the common weather picture. Global harmonization is addressed further in Chapter 8.

- **Automated and Human Decision Making**
  NextGen will build processes and systems that enable net-centric weather operations and weather integration into decision making that will help humans do what they do best — choose alternatives and make decisions — and help automation functions accomplish what they do best — acquire, compile, monitor, evaluate, and exchange information.

1.6 Concept of NextGen Weather

The JPDO Weather Working Group developed the *NextGen Weather ConOps* to define the required capability in a NextGen Enterprise. NextGen will integrate weather information and weather uncertainties into onboard avionics, NAS automation, and decision support systems. It will promote sharing of weather information and data, and replace the use of individual (and potentially conflicting) weather products with network-enabled common weather information

that supports an SSA. It will transform and integrate enhanced tailored, probabilistic weather information into NAS automation and decision support systems. It will use integrated weather information (including uncertainty), air traffic demand information, and other capacity constraints to analyze the integrated information picture in NAS automation tools. It will enhance weather availability, including enhanced weather observations and forecasts (including probabilities). It will provide linked automation on both the user side and the ANSP side, and it will extend to the cockpit enhanced weather information that is integrated with automated DSTs. This will include space weather information in the 4-D Wx Data Cube to meet needs of polar flights, near-space/space operations, and other space-weather related NAS impacts.

The ultimate goal of NextGen is to support safer, more efficient flight. The strategy for doing this is to support the proactive reduction in disruptions to the air traffic system, such as flight delays, by balancing demand with system capacity. This will provide user cost savings, enhance air transportation system efficiencies, manage for weather uncertainties, and support ATM and industry performance and service goals. It will enable users and service providers to more precisely identify specific weather impacts on operations (e.g., trajectory management and impacts on specific airframes, arrival/departure planning) and allow users and service providers to select among proposed mitigation strategies to balance demand to available capacity, both strategically and tactically. This will mitigate the disruptive impact of weather on flights because the extent and timing of weather-constrained airspace will be more precise, and it will enable automated negotiation of proposed strategies.

The NextGen Weather IOC team recognized the need to look at improving the weather information infrastructure before it could be incorporated into ATM decision-support processes. Several weather data architectures were considered during the development of the *NextGen Weather ConOps*. From the analysis of alternatives, the IOC Team selected a course of action to develop a new weather data distribution architecture, leveraging net-centric standards and existing architectures. This solution became known as the 4-D Wx Data Cube.

In addition to being the most cost effective solution, the 4-D Wx Data Cube overcomes the deficiencies of the other alternatives considered. This solution meets all NextGen goals and requirements, involves acceptable implementation risk, and allows for the provision of current regulatory weather products (e.g., convective Significant Meteorological Information [SIGMETs]). Policies are changed to transition the NAS from a “product” to an “information” environment. Additionally, it includes distributed data processing with centralized publication/subscription and it leverages net-centric data sharing standards across multiagency architectures in order to better accommodate the needs of different communities. The selected solution synchronizes with partner agencies already moving toward a Service Oriented Architecture (SOA), and uses much of the current baseline architecture to develop a consistent source of weather information for CDM.

1.7 Benefits to NextGen

1.7.1 4-D Wx Data Cube Benefits

Many of the 4-D Wx Data Cube benefits directly support the FAA's 2009-2013 Flight Plan and the capabilities required to provide increased capacity and margin of safety in the face of anticipated significant increases in demand. The FAA's Flight Plan, which is the strategic plan for the agency, describes the near term goals for NextGen for increased safety, greater capacity, international leadership, and organizational excellence. Some of these NextGen capabilities will be dependent upon the net-centric access of weather information and improved weather observation and forecasting capabilities, as well as the development of a common weather picture. These capabilities will also provide cost savings in common weather information tools and collateral enhancements to non-NextGen programs internal to NOAA and FAA.

The 4-D Wx Data Cube enables the point-to-multipoint, networked access of distributed observational and forecast weather information by all NextGen users, service providers, military planners, and security personnel. The 4-D Wx Data Cube will provide users with net-centric access to consistent tactical and strategic level weather information. The 4-D Wx Data Cube will employ Networked-Enabled Operations (NEO) data management techniques to access information across varied sources, and space and time scales. The 4-D Wx Data Cube will rapidly disseminate changes to weather information. For all categories of weather users, the 4-D Wx Data Cube will improve access to timely and accurate flight information to support improved decision making for increased capacity and enhanced safety.

1.7.2 Operational Benefits

Capacity management, trajectory management, flow-contingency management, separation management and improved surface operations are planned NextGen operational capabilities. Accounting for weather and weather uncertainty through the common weather reference and subsequent weather integration into DSTs supports the management and achievement of these capabilities. While both strategic and tactical benefits are envisioned, it is anticipated that the greatest benefits for all stakeholders will be more fundamental – NAS decision makers will be better able to effectively achieve NextGen mission goals by taking a more strategic approach to the influences of Mother Nature.

Traffic Flow Management (TFM) will utilize weather information for strategic decision making to support flow and associated contingency planning using TBO procedures as noted above. The elimination of disparate weather forecasts including improved weather information reliability and consistency via the common weather reference enables more efficient airspace use. Weather information is translated into airspace constraints that lead to flow contingencies well in advance of an aircraft's arrival in the area of the weather. DSTs utilize this constraint information to assess the range of possible impacts on proposed four-dimensional trajectories (4DTs) and related flows. This impact information serves as input towards the collaborative allocation of traffic flows that best achieve capacity balance, safety, and end user desires. Performance and management of these flows is further facilitated by the practice of using 4DTs to avoid weather-

constrained areas. This supports potential downstream workload reduction for Air Route Traffic Control (ARTCC) and Terminal Radar Approach Control (TRACON) managers and en route controllers. Consistency in weather forecasts and managing uncertainty as risks enables more precise decisions involving risk vs. benefit of possible contingency flows. This additionally serves to improve proactive CDM between traffic flow and Center/TRACON managers in the event of required contingency planning and execution. Contingency plans and their impacts can be formulated more effectively and decision making becomes more seamless over operational times, boundaries, and activities. Further, efficient removal of flow restrictions restores capacity against increasing demand consistent with the evolving weather conditions.

For TFM/ATM, use of NextGen weather for strategic decision making supports proactive planning for airspace/sector management. Strategic movement and planning of TBO-based traffic flow demands against contingency flows are more effectively managed based on improved CDM. NextGen weather supports the ability for traffic flows and aircraft within those flows to reach pre-described locations (time-based metering) that are congruent with capacity allowances and aircraft performance capabilities. While clear path 4DTs may not be possible, the objective is to reduce the impact of weather on operations so as to have sufficient improvements in safety to meet closer separation distances and greater traffic demand.

All NextGen operators and users benefit strategically through the access and use of NextGen weather. Based in part on their own unique corporate business rules and models as well as other economic drivers, flight planners determine desired fleet/vehicle trajectories (e.g., the business trajectory). Weather translation and impact fields as derived from the common weather reference support these trajectories. User preferred trajectories are based on stable weather uncertainties and incorporated constraints along with air traffic workload balance of demand with capacity and safety. Trial planning of desired or acceptable trajectory preferences via CDM with TFM and ATM fosters strategic pre-negotiation for flight trajectories. If the weather downstream changes unexpectedly while in flight, flight trajectory re-negotiation with ATM is facilitated collaboratively (with further collaboration with TFM for flow adjustment).

Tactically, ATM will benefit from NextGen weather (e.g., greater accuracy of winds, etc.) through the ability to determine and manage adjustments of flight tracks within flows. This can be offered to pilots through different 4DT opportunities to change routing, climb higher, descend, or change their timing. This supports the ATM anticipation of pilot requests to deviate and further reduces potential workload. Merging strategies and related contingency options are coordinated across ARTCC/TRACON/Terminal ATM based on weather information consistency among all users and uniquely quantified weather uncertainty. When combined with queued arrival/departure traffic and related 4DTs, NextGen weather information supports modeling of operational impacts to airspace reserved for merging (quantifies airspace capacity and impact). Controllers benefit as participating aircraft have the same weather information from which to coordinate should highly tactical maneuvers be warranted – such as alternative merging. If maneuvers are required, weather information parity (i.e., weather information derived from the same reference) between pilot and controller enables the identification and management of new trajectory paths and their respective conformance bounds. This refers to vertical and lateral

airspace volume needed for weather avoidance by the pilot and it ensures continued safe operations especially in highly congested airspace.

In the most tactical sense, if the weather changes unexpectedly within a localized area of the NextGen airspace, re-negotiation of a flight trajectory is supported through SSA of weather information parity between pilot and controller. However, it is envisioned that such tactical (more reactive) encounters will be reduced as more strategic flows and management planning integrate consistent weather uncertainty and impact fields into decision making.

NextGen weather provides direct benefits to pilots, as well. Strategically, flight deck automation will support assessment of flight-specific, pilot-defined weather thresholds of interest to ensure flight convenience, comfort, and safety. For example, pilots could set an acceptable turbulence level, icing zones to be avoided, and other pre-defined parameters. Risk-based automation tools, supported by unique weather uncertainties, provide alternative routing options in concert with pilot preference and company business rules. Consistency in observed or forecasted weather, as facilitated by the common weather reference, fosters greater collaboration between pilot, dispatch, and, in the event of proactive rerouting, ATM and TFM for flow adjustments.

Tactically, NextGen integrated weather facilitates determination of ascent and descent patterns (e.g., CDA), which lead to more efficient fuel burn. Properly equipped flight decks will have information parity with controllers and requests for deviation (within flows) can be handled more efficiently. ATC can provide the requested service (pilot benefit) while maintaining and effectively managing trajectories within the flow (e.g., conformance bounds).

1.7.3 Other Benefits

The benefits derived from the 4-D Wx Data Cube and net-centricity will drive ancillary improvements to weather sensing capability and access to common weather data. These improvements will propagate beyond NextGen. Improvements in aviation-driven, high-resolution modeling will enable NOAA to produce more accurate forecasts that support NextGen and the public. NOAA will also use the 4-D Wx Data Cube technology to improve access to all National Weather Service (NWS) products and services through their portion of the 4-D Wx Data Cube. The increased availability of networked weather information supports automated DSTs for other agencies and entities beyond the FAA. Information technology (IT) and data management enhancements to the 4-D Wx Data Cube will allow NOAA to establish a virtual repository and access for critical NWS products and services beyond aviation. It also extends the Advanced Weather Interactive Processing System (AWIPS) enterprise services into a “system of systems” linking disparate, incompatible NOAA systems. These two enhancements will support Global Earth Observation System of Systems (GEOSS) requirements and enhance continuity of operations for NOAA.

The idea that one could “data mine” information that was tied spatially and temporally to a common datum or frame facilitates truly coordinated decision making between and within agency users. Common weather data, information, and knowledge will enable pilots and aircrews to have SSA and shared responsibilities with controllers, dispatchers, flight service

station specialists, and others involved in preflight, en route, and post flight aviation decisions involving weather. Such common weather information, integrated into controller DSTs, will improve the efficiency of controller decisions, and greatly reduce controller workload during unfavorable weather.

The 4-D Wx Data Cube can reduce cost by eliminating the need for unique interfaces to support access to duplicate weather information, providing weather data access using common weather data formats and open standards, and developing reusable weather information access tools, software, and documentation. Reuse can greatly streamline software updates and change management strategies. The 4-D Wx Data Cube could also reduce the number of independent communication lines weather data subscribers need. The synchronization of 4-D Wx Data Cube developments can be achieved from complementary agency research and development focused on improved numerical weather prediction and aviation hazard prediction, as well as detection, automated decision rules, and net-centric weather data standards.

2 AGENCY SYNCHRONIZATION

This chapter describes the roles of the NextGen Agencies in accomplishing the activities described in Chapter 1 for developing a NextGen Weather Enterprise. It also describes the management structure being used to oversee the development efforts.

The overarching roadmap for developing a NextGen Weather Enterprise is provided in Figure 2-1. This roadmap highlights the involvement and dependencies of the various NextGen agencies. The details for fulfilling this roadmap are discussed in more detail in Chapters 3 and 4 of this Plan, however, the detailed agency tasks are captured in **Annexes 1** and **2**.

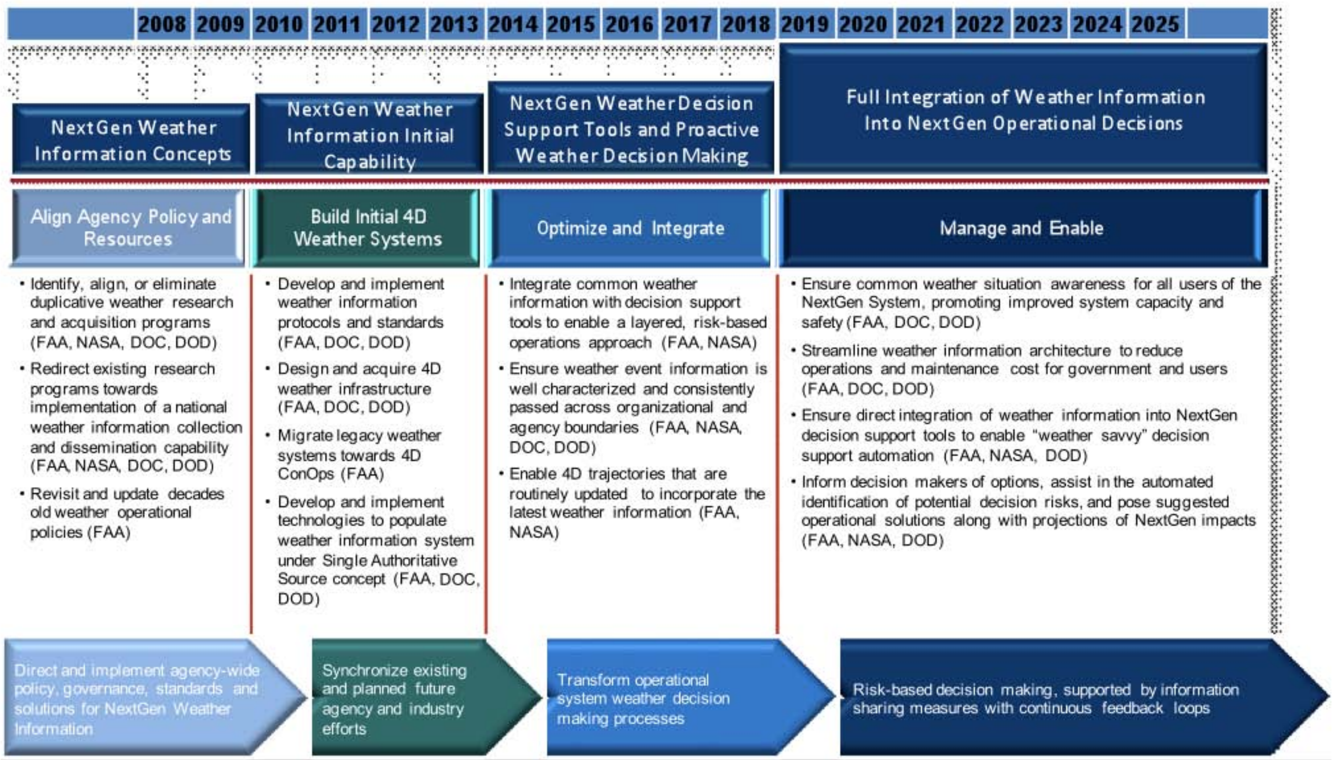

Figure 2-1 Agency Synchronization Roadmap

Although Vision 100[3] founded the JPDO, the JPDO does not have the execution authority to develop or deploy the 4-D Wx Data Cube or to integrate weather into NAS tools or establish procedures for NAS operations. This chapter is focused on synchronizing the various agency roles and responsibilities to develop and operate a NextGen Weather Enterprise.

[3] Public Law 108–176—DEC. 12, 2003, 108th Congress, Vision 100—Century of Aviation Reauthorization Act, Title VII - Aviation Research, Section 709, Air Transportation System Joint Planning and Development Office.

The tasks and agency responsibilities outlined in the Plan are focused on delivering capabilities required to meet NAS Operational Improvements (OI) as outlined in the JPDO Integrated Work Plan (IWP). These OIs are given below in Table 2-1.

Operational Improvement (OI)	JPDO IWP OI Title	Initial Operational Capability (IOC) Date	Office of Primary Responsibility (OPR)
OI-2010	Net-Enabled Common Weather Information Infrastructure	2013	Department of Commerce (DOC)
OI-2020	Net-Enabled Common Weather Information - Level 1 Initial Capability	2013	DOC
OI-2021	Net-Enabled Common Weather Information - Level 2 Adaptive Control/Enhanced Forecast	2018	DOC
OI-2022	Net-Enabled Common Weather Information - Level 3 Full NextGen	2022	DOC
OI-2023	Initial Integration of Weather Information into NAS Automation and Decision Making	2018	FAA
OI-2024	Full Integration of Weather Information into NAS Automation and Decision Making	2023	FAA

Table 2-1 JPDO IWP Weather OIs

2.1 Agency and Community Roles and Responsibilities

To define the roles of the agencies in building and operating a NextGen Weather Enterprise, the Weather Integration Concept outlined below separates the Enterprise into four major phases. These components or phases enable and enhance automated ATM decision making in the face of adverse weather. These components are ‘weather information,’ ‘translated weather,’ and finally, ‘impact estimates.’ The components and their interactions are illustrated in Figure 2-1.

Moving from left to right, Figure 2-2 shows the process beginning with weather data that describes the state of the atmosphere at a current or future time, continuing through translation of that data into weather constraint parameters, then through operational NAS impacts, and ultimately leading to ATM decisions. Portions of this process are highlighted with more detail in subsequent chapters of the Plan.

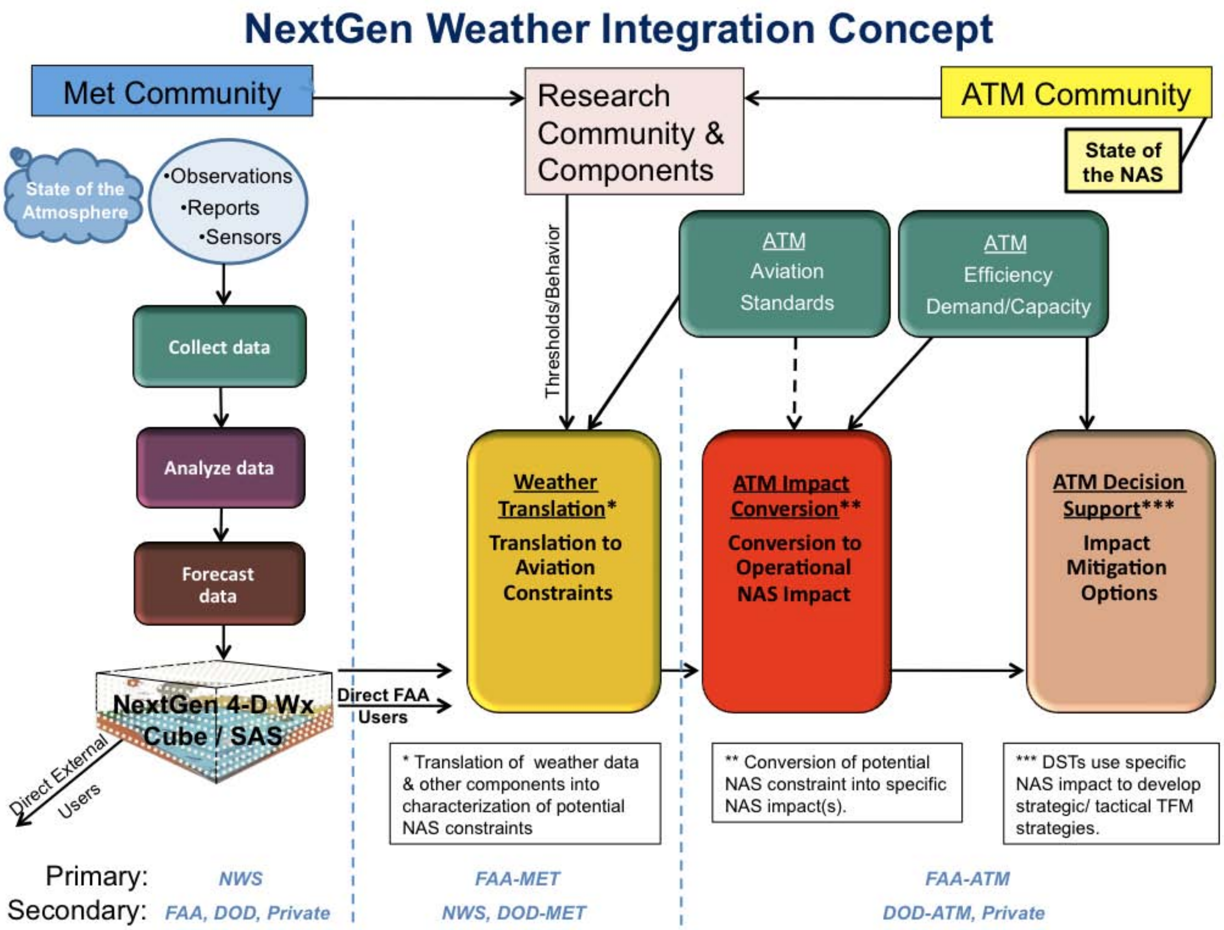

Figure 2-2 NextGen Weather Integration Concept

Weather Information and Weather Translation are the responsibility of the meteorological community. Each agency involved in NextGen Weather will have a lead role in the development of various portions of a NextGen Enterprise concept illustrated above. The cost of developing and implementing any capability presented in the Plan will be born by the user programs. Each agency's role is outlined below, however, in order to be successful, the agencies and their stakeholders, as well as private industry, must work together on many of these areas. The global community is also a key actor.

The FAA will have primary responsibility for the ATM-Weather Integration process. This includes weather translation, ATM impact conversion, and ATM decision-making functionalities because they own most ATM systems and the ATM-Weather Integration process resides primarily within the FAA. The FAA also has primary responsibility to direct research and development of aviation-specific weather information and functionality. The FAA will manage the Quality Management System (QMS) to oversee verification of operational aviation weather products to ensure compliance with the International Civil Aviation Organization (ICAO) standards. The FAA and NOAA have shared responsibility for the establishment of weather information exchange standards. The FAA will look to leverage integration efforts of other

agencies where feasible. However, for success, other agencies and stakeholders must be involved.

2.1.1 National Oceanic and Atmospheric Administration (NOAA)

NOAA is the lead for the development and implementation of the provision of net-enabled weather information. For more information on NOAA and the 4-D Wx Data Cube, see Chapter 3 and **Annex 1**. NOAA will support the FAA by providing expertise in the interpretation of weather information and in techniques for integrating weather. The Network-Enabled Verification Service (NEVS) being developed jointly by NOAA and the FAA will provide tools for verification of the data in the 4-D Wx Data Cube. Verification information is needed to support determination of the 4-D Wx SAS contents, to facilitate the future use of the 4-D Wx Data Cube data integration into DSTs, and for the QMS process.

2.1.2 National Aeronautics and Space Administration (NASA)

NASA will continue to be a major developer of ATM tools and techniques, as well as weather integration methodologies. NASA will share the results of its research and development with other stakeholders for implementation and deployment.

2.1.3 Department of Defense (DOD)

The DOD has developed, and is expected to continue to develop, tools and methodologies that have application to the civil aviation community, including some relevant to weather integration efforts. To the greatest extent possible, the DOD will share its developments with the broader NextGen weather integration community. With appropriate access and authentication controls, DOD will share weather data with civilian aviation sector. DOD will also cooperate in the development of weather integration capabilities when civil aircraft operate in military-controlled airspace, when civil aircraft operate at military airfields or joint-use fields operated by the DOD, and when the weather integration community considers the hand-off point/procedures of aircraft between civil and military control.

2.1.4 Private Sector

The Plan does not obligate the private sector to take any action. However, when weather-integrated ATM capabilities become operational, private sector users will be affected. To the maximum extent possible, writers and executors of the Plan will take the needs of the private sector into account, such as by refraining from unnecessary equipage requirements. Through the NextGen Institute[4], members of the private sector have helped prepare the Plan and will be encouraged to continue their participation. The Federal partners will make every effort to

[4] The NextGen Institute was established in March 2005 via a contract between the National Center for Advanced Technologies (NCAT) and the Federal Aviation Administration (FAA) "as the mechanism through which the JPDO will access world-class private sector expertise, tools, and facilities for application to NGATS activities and tasks." Ref.: National Center for Advanced Technologies.

involve the private sector and keep the private sector informed of any decision that may affect them.

2.1.5 Global

Both weather and aviation are international enterprises. As with other NextGen developments, the weather community will seek to harmonize NextGen weather capabilities with related international efforts, such as those in Single European Sky ATM Research (SESAR), ICAO, and the World Meteorological Organization (WMO).

2.2 NextGen Weather Management

To ensure the agency plans stay synchronized, the NextGen Senior Policy Committee (SPC) and JPDO Board established the NextGen Executive Weather Panel (NEWP). The NEWP acts as the primary decision-making body for issues related to NextGen Weather. Unresolved issues are elevated to the JPDO Board and/or SPC. It issues guidance on two primary activities: provision of net-enabled weather information and application of the weather information in NextGen activities. The NEWP annually approves the Plan, which will contain implementation timelines, identification and definition of critical milestones, and updates to the agreed upon roles and responsibilities contained in this document.

NEWP Membership includes:

- FAA Air Traffic Operations (ATO) Senior Vice President for NextGen and Operations Planning Services
- NOAA Assistant Administrator for Weather Services
- Air Force Director of Weather
- Oceanographer and Navigator of the Navy
- NASA Director of Airspace Systems Program Office
- JPDO Director

2.2.1 JPDO Weather Working Group Co-Chairs and the Executive Committee

The JPDO Weather Work Group (Wx WG) supports the NEWP in managing this multi-agency effort. The Wx WG coordinates two primary activities: the provision of net-enabled weather information (NOAA led) and the application of weather information into NAS operations (FAA led). The Wx WG (Figure 2-3) has four standing teams and two sub-teams to facilitate the Plan:

- 4-D Wx Data Cube Team

- Environmental Information Team
- Information Technology / Enterprise Services Team

- ATM-Weather Integration Team

- Policy Team

- Demonstration Coordination Team

Cross-agency issues are managed through the Wx WG Executive Committee, which is composed of agency leads and industry representatives, as well as government and industry Wx WG Team Co-Chairs.

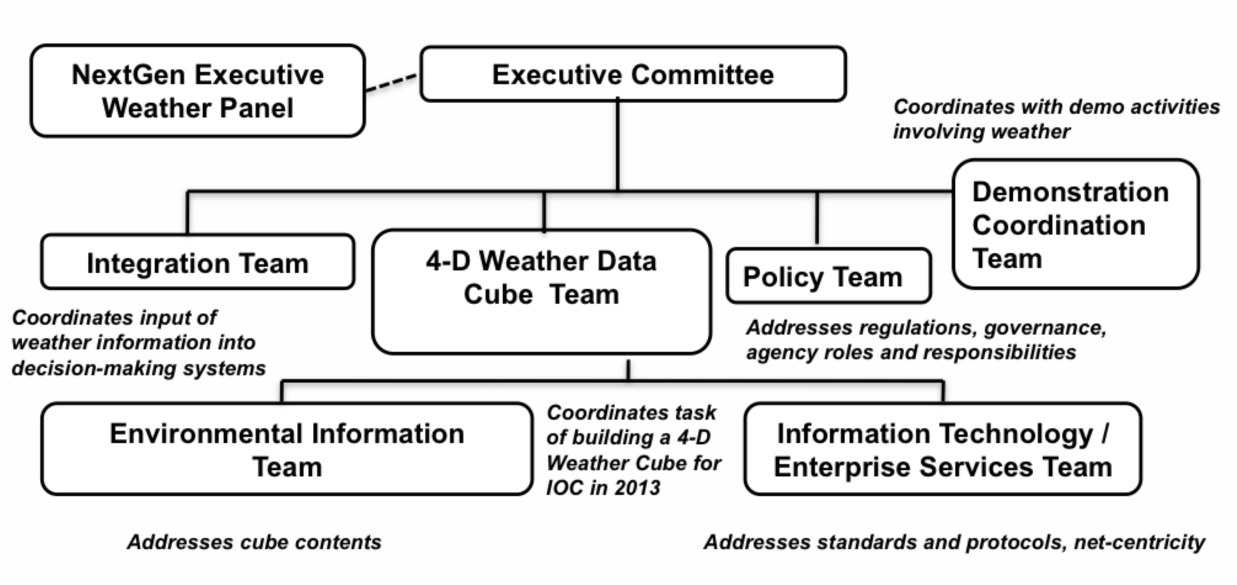

Figure 2-3 NextGen Weather Management and Governance Structure

2.3 NextGen Weather Enterprise Activity Funding

NOAA and the FAA provide a significant amount of the funding required for the development and implementation of their respective lead tasks. Other agencies identify relevant funding or internal programs that complement the development and implementation activities. All participating agencies agree to allow the synchronized plan to define tasks and preferred priorities for those particular funds.

2.4 NextGen Weather Plan Execution

As previously discussed, the development, test, deployment, and operation of NextGen Weather are a multi-agency effort. Because a single acquisition program to design, build, test, and deliver the constituent parts of NextGen Weather Enterprise is not possible, NextGen weather

capabilities are developed and managed across multiple independent but coordinated acquisition programs operating in parallel. Each stakeholder (government agencies and industry) has their own planning processes, budgets, authorities, legal mandates, culture, and operating missions to support their component acquisition efforts. The principle of synchronization requires that the JPDO Wx WG facilitate alignment of agency plans and programs toward a common purpose, and then ensure that their independent activities help to achieve this common purpose.

2.5 Agency Alignment

To successfully deliver a NextGen Weather Enterprise, the partner agencies need to align their individual plans and programs. The NextGen Wx WG will facilitate the interactions between the agencies to ensure budgets, schedules, and roadmaps are synchronized to meet user needs. This will facilitate discussions with the Office of Management and Budget (OMB), the White House Office of Science and Technology Policy (OSTP), and the Congressional Budget Office (CBO).

To ensure alignment, the agencies must work together to:

- Identify technical and programmatic interdependencies between agency programs
- Properly align schedules for planning, developing, demonstrating, integrating, and transitioning to operations across interdependent programs
- Ensure items being developed by one program that are on the critical path of another program are available in time for integration, testing, and transition and enable more efficient use of capital investments
- Establish metrics (risk, schedule, budget, performance, etc.) to monitor development and implementation status

2.6 Metrics

Metrics provide a measure of the degree to which interdependent acquisition programs are properly aligned. Metrics must measure the effect synchronization has on delivering operational capability on time, within agency constraints, and if synchronization meets requirements. They must measure the degree of success or failure in achieving synchronization for the system. Measurement should be repeatable to show trends and demonstrate the alignment of the programs' development life cycles relative to one another. Finally, metrics reports should contain a set of metrics reliably produced from the data, address program leadership needs, and lead to actionable recommendations on how to prevent or correct any synchronization issues.

The status of each agency's efforts in developing a NextGen Weather Enterprise must be readily available and measured against a baseline. Standard tools (earned value management system, risk management, etc.) will be used to track these tasks. The Wx WG Executive Committee will review these metrics on a regular basis to ensure programs are progressing as required.

3 NEXTGEN FOUR-DIMENSIONAL WEATHER DATA CUBE

3.1 Introduction

In the NextGen concept, weather information will come from a net-centric, virtual, data repository of aviation weather data, referred to as the 4-D Wx Data Cube. The 4-D Wx Data Cube's contents, and its supporting services, will provide NextGen Weather Enterprise registered users with access to global aviation weather information in a SOA network. This concept allows each agency to coordinate their existing, agency-specific efforts to fulfill aviation-weather requirements to provide a mutually-supportable national — and eventually global — construct. This Federal effort addresses a way to satisfy public and private sector aviation weather needs while allowing each agency to maintain various independent capabilities consistent with their own requirements. A foundational element of this effort builds upon and takes advantage of evolving information technology advances. NOAA, the FAA, and the DOD have developed a plan to ensure accessible, network-enabled weather information will be available to meet the needs of the aviation community. This plan, known as the *NextGen Four-Dimensional Weather Data Cube Plan*, is provided in **Annex 1**.

In its end state, the 4-D Wx Data Cube's contents consist of weather information (e.g., weather observations, analyses, and forecasts and forecast verification and probabilities, including the 4-D Wx SAS services and capabilities enabling exchange of the 4-D Wx Data Cube contents, which include but are not limited to:

- Registry/Repository (i.e., information discovery capability)
- Metadata (i.e., structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage an information resource. Metadata is often called "data about data.")
- Data access services (e.g., Web Coverage Service [WCS], Web Feature Service [WFS])
- Service Oriented Architecture (SOA) (i.e., an underlying computer systems structure that supports the connection between various applications and the sharing of data)
- Ontology (i.e., a feature that enables users to discover datasets registered in the Registry/Repository and the corresponding service endpoints, in a vocabulary-independent manner)
- Communication interface services (i.e., NOAA intra-network [NOAAnet])
- FAA Telecommunications Infrastructure (FTI) to provide weather data distribution functionality and publish/subscribe functionality
- FAA's System Wide Information Management (SWIM) system

- Weather forecast development (e.g., probabilistic forecasts, greater forecast accuracy and resolution) and availability

- Verification Services

In its end-state, the 4-D Wx Data Cube will connect weather sensors, weather processors, and collection servers containing weather information from government and certified industry suppliers that are distributed and networked across multiple locations. The locations are based, in part, on the ability to leverage or optimize current or planned capabilities at these facilities to collect, process, store, archive, and disseminate weather information.

As show below in Figure 3-1, weather state information will be generated (observed, analyzed, or forecasted) before becoming available and accessible in the 4-D Wx Data Cube. The 4-D Wx Data Cube will then manage and disseminate the resulting weather state information through a net-centric infrastructure. Weather information will flow from the 4-D Wx Data Cube to weather translation capabilities outside of the 4-D Wx Data Cube for constraint assessment and threshold determination. These translated constraints will then be disseminated to automation for integration into operational decision making (see Figure 2-2). Weather state information from the 4-D Wx Data Cube may also flow directly to FAA and other aviation users without a need for translation. Examples are flight level winds to be used in trajectory estimation calculations, or METeorological Aerodrome Reports (METAR) and Terminal Aerodrome Forecasts (TAF) employed in flight planning.

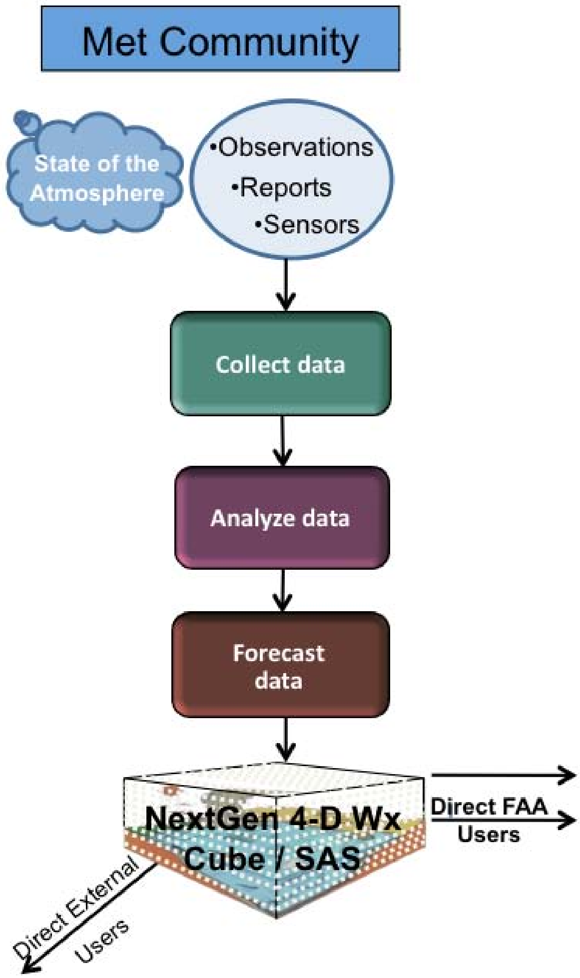

Figure 3-1 Weather information flow to the 4-D Wx Data Cube

Performance feedback information included within the 4-D Wx Data Cube (figure 3-2) will support the determination of the 4-D Wx SAS contents, which are also within the 4-D Wx Data Cube.

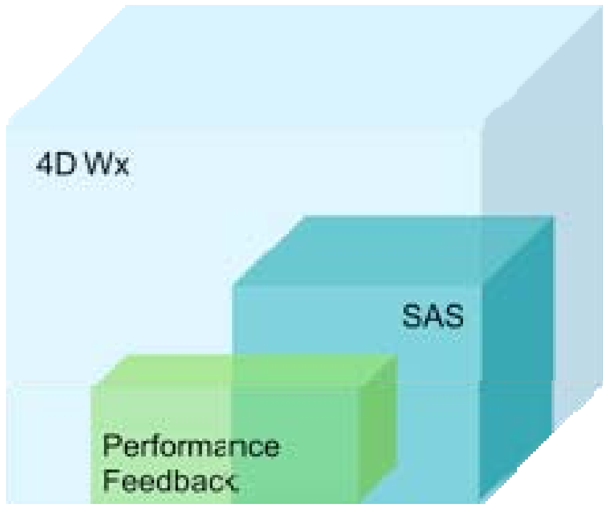

Figure 3-2 4-D Wx Data Cube and its relation to 4-D Wx SAS and verification

The development of the 4-D Wx Data Cube will be a multi-agency task. Identifying the required content, how it will be populated, verified, and distributed will require a coordinated, multi-agency effort. For IOC (2013-2015), the 4-D Wx Data Cube will contain weather information from ground, air, and space-based sources that support legacy (current) observational and weather forecasting/processing platforms. This will include information from supporting Agency weather radars, weather satellites, aircraft (onboard sensors and pilot reports), weather products in traditional alphanumeric forms (e.g., TAFs, METARs), surface observations, model outputs, and forecast products. The 4-D Wx Data Cube will also contain some weather state information from outside FAA controlled airspace.

At IOC, the 4-D Wx Data Cube's contents and its supporting services will provide the infrastructure required to support NextGen operational decisions. Subsequently, ATM systems and users will begin accessing this information to enable their decision making. In order to support NextGen initiatives, the weather state information collected and contained in the 4-D Wx Data Cube will evolve throughout the development of NextGen. In future developments, the breadth of weather state information within the 4-D Wx Data Cube will change to include additional sensor, model, and forecast information, including improvements in accuracy, update rate, and resolution. The 4-D Wx Data Cube will also support probabilistic analyses and forecasts and forecast verification in accordance with decision-support needs. Participating agencies and industry will need to conduct extensive and coordinated research and development to meet many of the future NextGen requirements.

3.2 NextGen 4-D Wx Data Cube Description

At final build-out in 2022-2025, 4-D Wx Data Cube data will include public domain, unclassified weather information relevant to aviation decision making, including human and machine-derived observations (ground, air, or space-based), analyses, and forecasts (text,

graphic, gridded), model information, and climatological data. Foreign, proprietary/private sourced products will also be included with appropriate safeguards developed for the information, as deemed necessary. Primarily, NOAA and FAA will publish data that form the 4-D Wx Data Cube, but other approved sources may publish, as well. Information in the 4-D Wx Data Cube will be tagged with metadata to allow users to access the necessary information required to complete a task (flight planning, reroute, fuel load, etc.). The contents, access, and utilization of the 4-D Wx Data Cube by NAS users' operational applications are foundational NextGen Weather capabilities.

Networked weather state information within the 4-D Wx Data Cube will be secure, distributed, and easily expandable to accommodate increased performance requirements (e.g., larger volume, greater complexity, higher-fidelity weather data for automation ingest, and low latency information for immediate user response or increased user base). The 4-D Wx Data Cube's contents and its services will provide users access to information shared in standardized protocols and formats universally acceptable with controlled exchange structure and services. 4-D Wx Data Cube services will facilitate communication and collaboration across time and space boundaries to achieve common, mission objectives. It will also be independent of the underlying communications infrastructures.

The 4-D Wx Data Cube's capability will be dependent upon a cross-agency supporting infrastructure that consists of software, such as that needed to implement Open Geospatial Consortium (OGC) web services and registry/repository software, the hardware to host the software, data access services, the SOA services (such as FAA's SWIM), and communications networks such as the FAA Telecommunications Infrastructure and NOAANet.

In 2013, NOAA will field an Initial Operating Capability (IOC) of its portion of the 4-D Wx Data Cube, with a limited number of applications (e.g., forecast verification) and an initial, rudimentary capability to designate data for the 4-D Wx SAS. Additionally, a large subset of all planned aviation weather elements will be available at IOC.

In 2015, the FAA will field an IOC of its portion of the 4-D Wx Data Cube to utilize NOAA-generated weather state information and disseminate FAA-generated weather information available to aviation users. The FAA will also add weather state information (e.g., Automated Surface Observing Station [ASOS], radar) from FAA systems into the 4-D Wx Data Cube.

By 2018, capabilities resulting from the research to produce and use high-resolution weather information will be in place or approaching readiness and additional weather types will be included such as space weather and volcanic ash. Furthermore, forecast verification will be enhanced, probability information will be introduced, and 4-D Wx SAS designation will begin to evolve from human- to machine-based.

By 2025, all the advanced capabilities currently envisioned for 4-D Wx Data Cube services, content, the 4-D Wx SAS, and forecast verification will be implemented.

3.3 4-D Wx SAS

The 4-D Wx Data Cube facilitates the development of the common weather reference called the 4-D Wx SAS from disparate sources of weather information. The 4-D Wx Data Cube's services include capabilities to deliver 4-D Wx SAS weather information in formats ready for translation into weather constraints, or direct use by decision makers.

3.3.1 4-D Wx SAS Definition

The 4-D Wx SAS is an optimal representation of all ANSP weather state information used directly or translated into operational impact by the ANSP, and is consistent in time, space, and among weather elements. The 4-D Wx SAS requirements are specified by the ANSP and the 4-D Wx SAS is accessible to all users of the NAS. The 4-D Wx SAS is the source of weather information for ANSP's ATM decisions and is supported by the same network services as the 4-D Wx Data Cube.

The ANSP will specify characteristics of weather state information needed to support its ATM decision making and DSTs. As NextGen capabilities mature, the ANSP requirements will evolve. NWS will, in coordination with Air Force/Navy weather services, determine what weather state information best meets the 4-D Wx SAS requirements specified by the ANSP. Information from any source, including commercial sources, can be used to meet 4-D Wx SAS requirements as long as can be freely distributed to all.

With rare exceptions, the 4-D Wx SAS will be the only source of weather information to support the improved efficiency of the ANSP's ATM decisions, however, it will not necessarily be the only source for other decision makers, such as pilots, dispatchers, and military operators. Making the 4-D Wx SAS both a support tool for the ANSP's ATM decisions and a NextGen resource provides both transparency and predictability in these decisions and SSA for all NextGen participants.

3.3.2 4-D Wx SAS Evolution

The success of the 4-D Wx SAS depends on the ability to provide weather information of value for NextGen operations that will facilitate increased utilization of NAS resources (e.g., airspace and airport capacity) while maintaining safety. This will require a robust effort to develop optimized weather element representations from multiple sources. It additionally means aligning planned 4-D Wx SAS functionality and data content with appropriate NAS OIs in the timeframes envisioned for OI implementation. The key to this will be two-fold:

- Weather information must be available in the appropriate timeframe so that the delivery of the information is matched with the operational readiness for proof of capability. This means that required weather information is available when the DST or other ATM functionality is operationally ready to deliver the NextGen capability.

- Weather state information of sufficient fidelity needed to support the capability must be available. The weather information needs to have the appropriate fidelity to support emerging NextGen OI capabilities.

At 2015, an initial 4-D Wx Data Cube capability with a limited number of applications available to use 4-D Wx SAS data means that only a subset of all planned aviation weather elements will be available. At a minimum, these include turbulence, icing, convection, ceiling, visibility, and wake vortex displacement. Operations-based accuracy and consistency measures will need to be developed to assess and validate the integrity of the data.

By 2018, capabilities resulting from the research to produce and use high-resolution weather information will be in place or approaching readiness. Only a few functionalities such as the production and use of probabilistic forecasts (limited in 2018) will not be available until full 4-D Wx SAS capability at 2023.

4 NEXTGEN ATM-WEATHER INTEGRATION

In previous chapters, the solution to the problem statement described how the 4-D Wx Data Cube would be designed and built to form and deliver common weather information that NextGen will use through automation. NextGen will innovate the integration of weather information into the decision-making process. This Weather Integration Phase, herein referred to as "Integration," is an overlapping phase in the Plan in which weather information developed in the 4-D Wx Data Cube is used in automated DSTs to achieve one of eight key capabilities established in the *NextGen ConOps*, "Weather Assimilated into Decision Making."

To facilitate this innovation, the *NextGen ATM-Weather Integration Plan* has been developed to address this challenge by describing user needs and outlining the intended implementation roadmap to achieve the NextGen vision. It also addresses agency roles and responsibilities and includes resource requirements. The *NextGen ATM-Weather Integration Plan* is provided as **Annex 2** of the Plan. It describes the relationship between weather integration, ATM tool developers and the major Aviation Weather Group programs, for example Reduce Weather impact (RWI), NextGen Network Enabled Weather (NNEW), Weather Technology in the Cockpit (WTIC), and Aviation Weather Research Program (AWRP).

The broadly collaborative approach of the *NextGen ATM-Weather Integration Plan* is to assemble teams of operations, programmatic, and meteorological personnel that are aligned with each solution set to analyze weather integration requirements for a service and performance-based approach for weather integration as associated with operational relevance. These teams will identify the specific weather integration need and insertion points, including performance criteria and value, into ATM tool or decision platform functionality, and then identify and recommend the specific weather integration technologies and other technologies that best fit the requirements of a particular TFM tool under development.

4.1 Weather Integration Concept

In the NextGen concept, weather information used by ATM decision-makers will come from a net-centric, virtual, data repository of aviation weather data: the 4-D Wx Data Cube. The action of taking weather information from the 4-D Wx Data Cube and using it in sophisticated DSTs that formulate the most efficient air traffic routing solutions and continually account for inherently dynamic weather phenomena allows NextGen stakeholders to make informed decisions affecting a variety of coordinated operations from flight planning to TBO to Ground Operations. ATM-Weather Integration development activities are underway. As operations models are refined and synchronized with air traffic flow management (ATFM), they depend more and more on timely and accurate weather information. As the 4-D Wx Data Cube develops, there is a natural progression toward incorporating this weather information into more sophisticated DSTs that continue to optimize resources for these operations.

This concept allows each Federal agency to leverage and merge their existing agency-specific efforts and aviation-weather requirements into a mutually supportable national, and eventually

global, construct. This Federal effort addresses a way to combine public and private sector aviation weather needs into the ATM process as well as allowing each agency to maintain various independent capabilities consistent with their own weather needs. The weather communities within NOAA, FAA, and DOD have developed the Plan to ensure accessible, network-enabled weather information will be available to meet the user's integration/operation needs.

4.2 Weather Integration Context

As described in the previous chapter, weather information is managed by the 4-D Wx Data Cube and disseminated through the net-centric infrastructure. Weather information flows from the 4-D Wx Data Cube to the weather translation component (Figure 4-1).

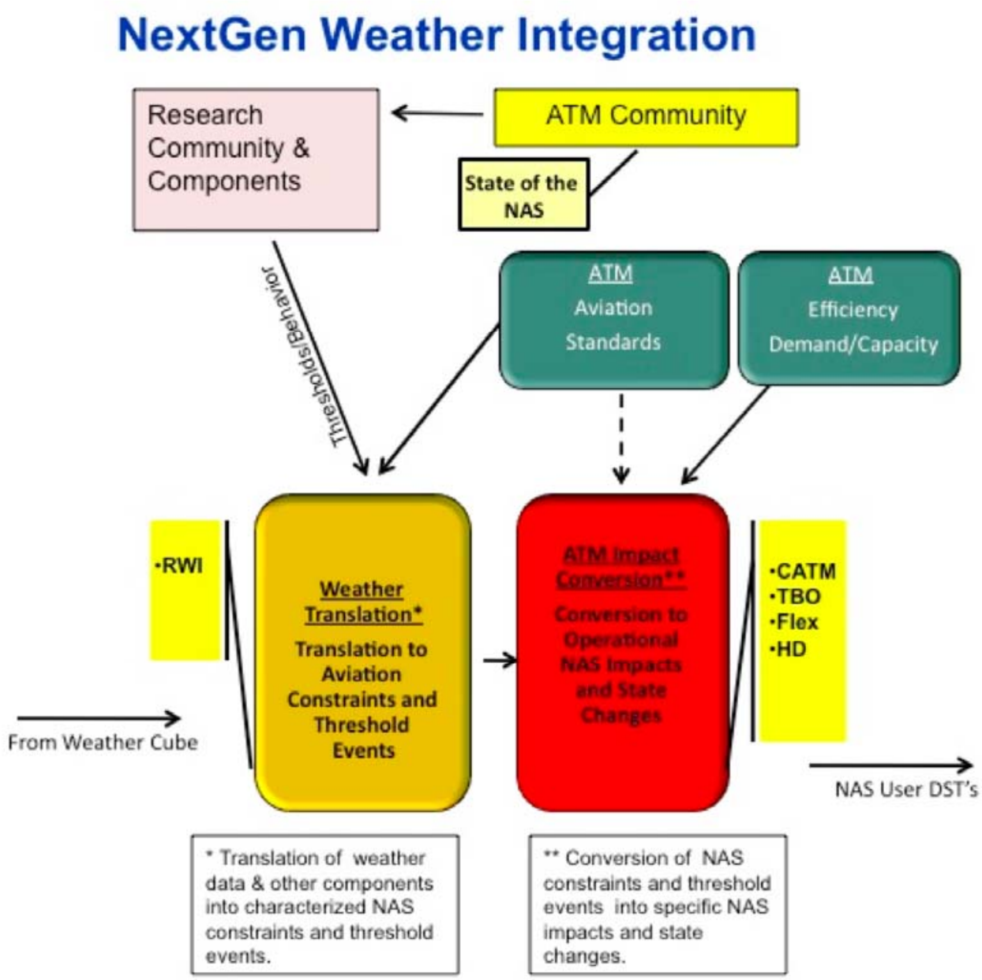

Figure 4-1 NextGen Weather Integration Concept – ATM-Weather Integration

Weather Translation transforms weather information through Federal Aviation Regulations (FAR), flight standards, aircraft limitations, and Standard Operating Procedures (SOP), into

operationally meaningful, weather-related values such as threshold events and/or characterized NAS constraints based on all possible aircraft types. The major source of the weather information for weather translation is thought to be the 4-D Wx SAS component of the 4-D Wx Data Cube.

Following weather translation, separate downstream ATM Impact Conversion takes the threshold events and/or characterized weather constraints, ATM aviation standards, and ATM efficiency demand/capacity and converts them into forecast NAS state changes or capacity impact values. NAS operators will have the option of accessing this constraint information in order to help understand the ANSP rationale behind ATM strategies. In every case, safety is one of the factors considered by ATM Impact Conversion functionality. Weather Translation output information as well as threshold, constraint, standards, demand, and capacity information will be available to users, however, these data and functionalities are all outside the 4-D Wx Data Cube and their location is yet to be determined.

Ultimately, the culmination of this process will feed these impacts into various ATM DSTs and displays, which operate in all time horizons from tactical to long-term strategic, to be available to the ANSP decision makers to assist in the development of appropriate ATM strategies. In this way, ANSPs will be able to use a common picture of weather constraints in their decision making, rather than having to develop individual (sometimes conflicting) interpretations of the underlying meteorological information. ANSPs will use DSTs to predict how individual aircraft will react in the face of the forecast weather hazard, or whether or not they will be able to continue to operate subsequent to the NAS state change. This, in turn, allows them to predict changes to the capacity of the affected NAS element. These tools use the NAS impact analysis results to develop traffic management plans (tactical through strategic) that suggest the best operating strategies to deal with forecast changes of state of NAS components or that best mitigate the effects of the forecast set of constraints. These tools will facilitate planning and coordination with the affected NAS elements and to inform ATM decision making, such as the CDM process.

4.3 Development

The Integration effort will act as an intermediary between the weather IT community in the development of the 4-D Wx Data Cube and the user system owners (ANSPs) to ensure that appropriate weather-related information flow occurs. The development of Weather Translation functionality and ATM Impact Conversion functionality will require concurrent involvement of both the meteorological and ATM communities. The Integration portion of the Plan is intended to address weather integration into ATM decisions made by the ANSP or by the ANSP in collaboration with the Flight Operations Center (FOC) or operators. FOC and flight deck decisions unique to the operator (i.e. excluding ANSP participation) are not addressed for development in the Plan. Those are principally left for market innovation to develop and implement.

Currently, the FAA is the lead agency charged with developing integration tools. The FAA's *NextGen Implementation Plan* includes the RWI Program. Activities in the near term will focus on:

- Developing a concept of use and initial requirements for weather dissemination
- Preparing for and conducting a weather dissemination interoperability demonstration
- Developing a concept of use and requirements for weather information needed by manual and automated traffic management and cockpit decision support tools
- Assessing gaps and redundancies in the current aviation weather observation networks
- Developing a pre-prototype multifunction phased array radar
- Developing improved forecasts (e.g., convection, turbulence, icing)

Weather integration in NextGen will be an evolving process. Initially, weather information systems will be stand-alone requiring manual integration. By 2013, some weather data will flow machine-to-machine (M2M), either through a weather translation process or directly (depending upon the application) to enable integration into DSTs. Most integration of weather information will still be handled manually but with improved "high glance value" displays. Some of these displays will include translations of state of the atmosphere data into potential NAS constraints. Some new data and displays will be provided to the cockpit for pilot decisions in collaboration with the ANSP. By the 2018 mid-term, some User-in-the-Loop Tools with M2M interfaces and algorithms suggesting solutions to the user for acceptance, rejection, or modification will begin being implemented. Many new datasets will be available that translate weather information into threshold events or NAS constraints.

By 2025, weather information will be automatically translated to threshold events or NAS constraints and ingested into most decision algorithms, both on the ground and in the cockpit but weather per se will not appear in the output decision at all. Whether the output decision takes the form of a human-readable display, or is relayed to a larger decision support mechanism, automated integration basically renders weather transparent to NextGen decision makers. Probabilistic weather data will introduce more complexity; e.g. the DST will have to compare input risk tolerance to probabilities of occurrence of the relevant weather phenomena in order to render a decision-quality output. For instance, a particular flight may be able to tolerate a 30 percent probability of thunderstorms along the planned route of flight, but it could not tolerate a 70 percent probability, in which case alternatives would be sought.

Development of tailored DSTs will be largely the province of the commercial sector where there is tremendous opportunity for ingenuity in applying weather to a whole range of decisions. The prime requirement for the weather community is that the weather information available by subscription from the 4-D Wx Data Cube be in a form, at a resolution, and at a quality level that meets user needs and can be readily translated into weather constraints, and further into impacts for assimilation for user DSTs. In order for this integration to be successful, human factors

research needs to be conducted to ensure that developers understand how weather is used in decision making so that the impact of weather data can be correctly translated for DSTs. This research will also be critical in determining the level or amount of weather transparency needed given the user's role in decision making. In some cases, anomalies or special circumstances may require users to view weather data as opposed to DST output. Information Management and Storage (IM&S) of products generated by weather translation, DSTs and other tools is also of interest.

5 NEXTGEN WEATHER POLICY

5.1 Policy Planning Areas

The JPDO Weather Working Group Policy Team 2 (Wx Policy Team 2), established under the JPDO Weather Working Group, is developing the policies and governance structure needed to manage the provision of weather information for NextGen.

The 4-D Wx Data Cube and 4-D Wx SAS, as described in Chapter 3, are foundational concepts for NextGen and represent a fundamental change in the provision and use of aviation weather information in the NAS. FAA and NOAA are developing the 4-D Wx Data Cube and the 4-D Wx SAS in concert with other Federal agencies and industry stakeholders. The Wx Policy Team 2 is using the framework, approach, and schedule described below to complete this effort before 2013.

5.1.1 Wx Policy Team 2 Framework

All participants in the 4-D Wx Data Cube will fall into one or more of the following categories:

- **Publishers** create weather information (both public and private)
- **Subscribers** access weather information (both public and private)
- **NextGen Weather Governance** will establish and enforce the rules for Publishers and Subscribers

As a condition of participation, providers must agree to follow rules[5] established by the NextGen governance and to make service information available (publish) to subscribers in accordance with these rules. As a condition of participation, subscribers must also agree to follow rules established by the NextGen weather governance or publishers.

5.1.2 Wx Policy Team 2 Approach

Within this framework, the Wx Policy Team 2 intends to define the categorical contents of the 4-D Wx Data Cube. The Wx Policy Team 2 will also formulate the initial rules for publishers and subscribers, and identify and establish the required NextGen weather governance structure.

[5] Policy Team will need to establish initial rules for Publishers and Subscribers until NextGen Governance is established and assumes this role.

5.1.3 JPDO Weather Working Group Policy Team 2 Schedule

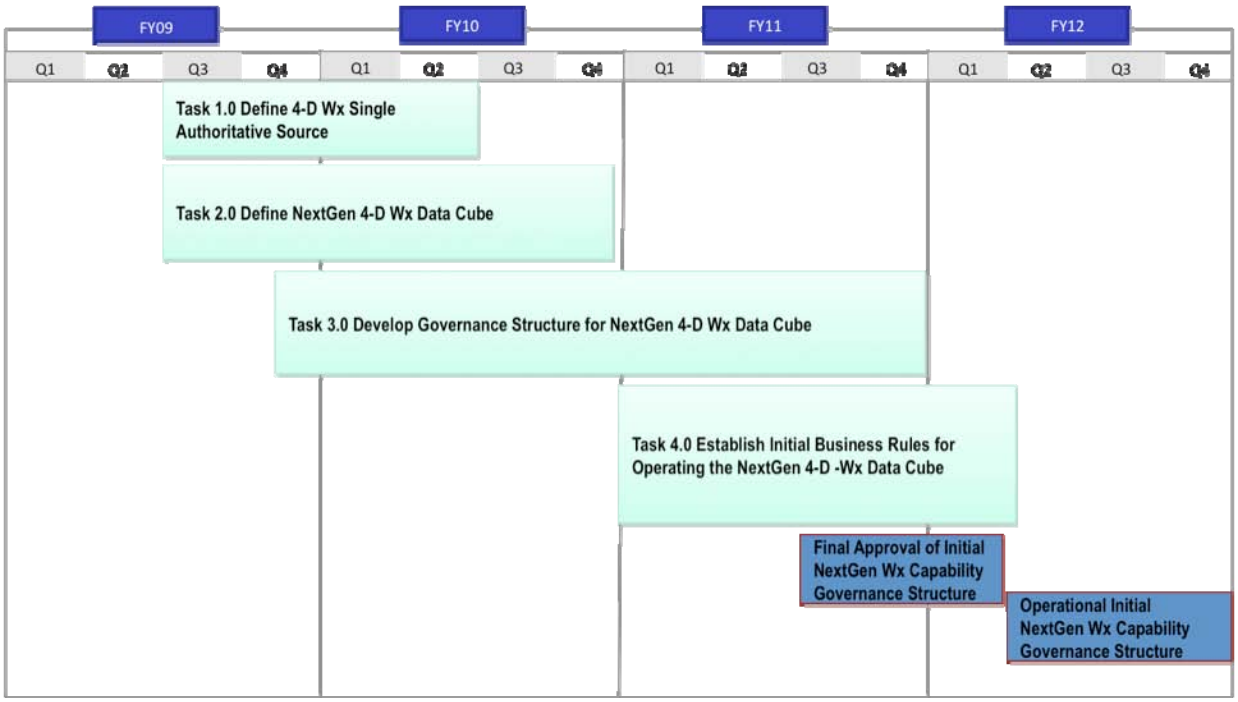

Figure 5-1 High Level Weather Working Group Policy Team Work Plan

Task 1.0 on the Wx Policy Team 2 work plan was to define the 4-D Wx SAS in policy terms so that it could be included in the governance model for the 4-D Wx Data Cube. The 4-D Wx SAS definition was circulated throughout the JPDO and amongst the partner agencies for approval. In June 2009, the NextGen Executive Weather Panel (NEWP) approved the definition of the 4-D Wx SAS. A detailed description of the 4-D Wx SAS can be found in Chapter 3.

The Wx Policy Team 2 is currently defining the content, publishers, and subscribers of the NextGen 4-D Wx Data Cube as part of task 2.0. This entails defining the content, publishers, and subscribers of the 4-D Wx Data Cube in policy terms. An initial description of the 4-D Wx Data Cube can be found in Chapter 3.

Task 3.0 is to develop the initial governance structure for the 4-D Wx Data Cube and 4-D Wx SAS. The Wx Policy Team 2 reviewed current governance models in the attempt to repurpose principles from current governance models to formulate the governance for the 4-D Wx Data Cube. The Wx Policy Team 2 is currently drafting the initial governance concept. Upon receiving concurrence from the NEWP, the Wx Policy Team 2 will develop the framework and the formal documentation necessary to implement the 4-D Wx Data Cube governance structure.

The final task for the Wx Policy Team 2 is to establish the initial business rules for operating the 4-D Wx Data Cube. Once the initial business rules for the 4-D Wx SAS and the 4-D Wx Data

Cube are identified by the Wx Policy Team 2, the NextGen governance structure will assume responsibility for the 4-D Wx SAS and the 4-D Wx Data Cube.
The last two items on the Wx Policy Team 2 work plan are not exclusively Wx Policy Team 2 tasks, however, these steps must be completed prior to implementation of the 4-D Wx Data Cube in the NAS.

5.2 Governance

The goal of the Wx Policy Team 2 is to facilitate the implementation of the governance structure necessary to operate the 4-D Wx Data Cube and 4-D Wx SAS in 2013 by developing and coordinating the policies necessary to establish and operate the governance structure.

The primary objective of the Wx Policy Team 2 is to establish the governance structure for the 4-D Wx Data Cube and 4-D Wx SAS such that it is operational in 2012.

6 NEXTGEN WEATHER DEMONSTRATION COORDINATION

Based on direction from the NEWP, the JPDO Wx WG has established a NextGen Weather Demonstration Coordination Team (Demo Team) under the leadership of the NextGen Weather IOC Team. They lead the effort to categorize and coordinate the various demonstrations of NextGen weather capabilities.

6.1 Goals and Objectives of Demonstration Coordination Team

6.1.1 Create and Manage a Centralized NextGen Demonstration Inventory

The principal objective is to build a formal inventory of weather demonstration information. This inventory will include current and proposed demonstrations from multiple government agencies, specifically FAA, NOAA, NASA, and DOD. This inventory will additionally include information from private industry and NextGen contributors as deemed appropriate. Both weather community specific demonstrations, as well as NextGen demonstrations that may benefit from the assimilation of weather data will be inventoried. The Demo Team will manage and update the demonstration inventory.

6.1.2 Facilitate Information Sharing

The goal of creating the inventory is to provide a complete and comprehensive demonstration inventory, which will ensure that access to information is available to interested authorized parties. Understandably, the level of detail made public may be restricted by private agencies looking for a competitive advantage.

6.1.3 Analyze Demonstration Gaps

The primary utility of the demonstration inventory is to help users identify gaps in demonstrated capabilities. Users can monitor the demonstration inventory to identify potential gaps in areas that need exploitation. Users can also evaluate demonstration content and use the inventory as a medium to suggest topics for additional work. Finally, users can recommend or share processes to monitor and evaluate demonstration inventory for the benefit of their programs.

6.1.4 Assume Demonstration Coordination Guidance Responsibility

The Demo Team supports synchronized governance of demonstrations by soliciting cooperation and coordination of future demonstrations among program managers and technology development agencies. The Demo Team urges agencies and private industry to participate in the demonstration inventory, or to reach out to a Demo Team member to assist with future coordination. For example, this could include contact information of partners working on similar endeavors, or more detailed information on supporting activities.

6.2 The Demonstration Inventory

Demonstrations will be catalogued into one of four categories. They are defined as follows:

- **Environmental Information**: These demonstrations focus on the science of observing and forecasting meteorological conditions that meet the demanding functional and performance requirements emerging with NextGen.

- **Information Technology**: These demonstrations focus on the information technology, including communications, used for the dissemination, storage, and access of weather data via SOA.

- **Interpretation/Decision Support**: These demonstrations focus on how weather observation and forecast information are applied to ATM-Weather Integration.

- **Potential Demonstrations**: This category includes two different types of demonstrations. First, there are potential demonstrations that are currently in the early planning stages and may not be sponsored or funded yet. Secondly, this category includes capabilities outlined in the Plan and in the *ATM-Weather Integration Plan* that are not currently planned for demonstration.

The demonstration inventory will not contain all details about demonstrations. Rather, key information will be included in the inventory, which will provide an overview of the demonstration and can direct parties to the proper points of contact to get more information.

The following is a list of demonstration parameters that will be tracked for each demonstration:

- Demonstration Title
- Demonstration Category
- Last Update
- Objective
- Description
- Start and End Dates
- Complete or Uncomplete
- Funding source(s)
- Agency Program

- Performing Organization
- Location
- Weather Phenomena
- Is the output format net enabled
- NextGen Solution Set Addressed
- POC E-mail and Phone Number

Demonstration planning is a constantly evolving process. For this reason, the demonstration inventory will be continually updated whenever new information is available. This will require effective communication between programs that plan demonstrations and Demo Team members who are tracking these efforts. The NextGen Weather Demonstration Inventory is provided in **Annex 3**.

6.3 Outreach

To facilitate the information exchange described in the previous section, a coordinated outreach effort to many communities of interest is necessary. Relationships must be built between Demo Team members and the agencies, programs, and industry partners who are performing these demonstrations. The Demo Team will perform outreach using such methods as letters, surveys, and participation in public forums. The connections built through this outreach will also be used to aid in the coordination of future demonstrations between potential partners.

6.4 Weather Integration in Non-Weather Demonstrations

In NextGen, the effects of weather, including space weather, will impact the improved operational capability envisioned. Unfortunately, such effects have not been identified as an element within many non-weather demonstrations or proof of concepts. There are several ongoing or planned non-weather demonstrations (e.g., Optimized Profile Descents [OPD], Staffed Virtual Towers, etc.) designed to test and validate early or near-term NextGen desired capabilities. Furthermore, there are other ongoing activities that are still emerging from the research world (e.g., Re-route Impact Assessment [RRIA], Collaborative Trajectory Options Program [CTOP], etc.). The inclusion of weather information has not been identified.

6.5 Demonstration Coordination Strategy

The Demo Team and operational communities, including the users, will work together to identify other non-weather demonstrations whose envisioned outcomes can be affected by weather. Opportunities for collaborative or supporting demonstrations allow the weather community to

design the functionality (e.g., net-centric weather access and availability) to make the required weather information available, with the necessary fidelities, to support NextGen operations.

6.6 Demo Team Support

The Demo Team will support weather integration into non-weather demonstrations by facilitating awareness of such activities to the weather community via the demonstration inventory database. The team will suggest alignments for ongoing or planned weather demonstrations with likely non-weather demonstrations to help quantify supporting roles of weather and more importantly, to identify possible gaps in weather demonstration capabilities. This includes a high-level approach for alignment or "best fit," as well as methodologies for gap identification. Additionally, the team will serve as outreach to coordinate and provide status updates on all the demonstration initiatives, alignments, and gaps.

7 NEXTGEN WEATHER SCIENCE AND TECHNOLOGY ROADMAP

7.1 Introduction

As NextGen weather evolves toward the net-centric environment described earlier in the Plan, the current weather technologies will also need to evolve to meet the new paradigm. Science and technology developments will be needed to ensure the fielding of digital information envisioned by the 4-D Wx Data Cube and the 4-D Wx SAS. The JPDO partner agencies must review their science plans and roadmaps to identify gaps in research areas and fill those gaps as needed. The consequences of ignoring these needs is that we will be unable to meet increasing demands on the NAS in capacity, efficiency, safety, and on reducing aviation's environmental impact. This chapter defines high-level milestones that will lead to decisions to implement policies, procedures, or technologies for achieving NextGen's OIs[6].

The primary drivers for NextGen Weather research are user needs for improved weather information, weather information sharing, and the integration of weather information into ATM decision making. The science and technology roadmap looks forward to 2025 to chart the major directions of aviation weather science, set the course of research activity that would best serve the needs of NextGen stakeholders, and assist decision makers and advocates for the research system to plan the allocation of resources for future NextGen weather program areas.

Maintenance research to support technology life extension programs must be sustained to protect past gains. Additionally, basic research must be supported to meet emerging needs. Much must be accomplished before many of the envisioned technologies become standard practice. It can be expected that these technologies will enable NextGen OIs. The expected benefits from successfully accomplishing the vision of this research activity would be greater safety, increased capacity, greater efficiency in managing capacity against demand, and profitability for the aviation industry and the economy as a whole.

The guiding principles for the next 15 years are simple: leverage advances in SOA and improvements in computing power and take advantage of emerging basic scientific discoveries and new technologies in weather to satisfy NextGen requirements. These principles must support a major paradigm change in the way weather is used to support ATM decision making. Furthermore, we need to take a multi-agency collaborative approach to product development, create opportunities for industry involvement, respond to the need for global harmonization, and enable the reduction of environmental impacts from aviation.

Our objective is to focus research activities on the most promising areas in ways that provide economic, safety, and environmental benefits. This will require research investments in terrestrial and space weather, communications, information systems, DSTs, and research that build on traditional and non-conventional approaches to problem solving. It will require

[6] A comprehensive NextGen Weather R&D Plan will be developed in the coming months as Annex 4 of the Plan. It will be aligned to the NextGen R&D Plan FY 2009 – FY 2013, 31 August 2007.

partnerships with the private sector where the implementation of many of these new technologies will occur. This will also require industry acceptance, increased research in weather dissemination and integration in DSTs, increased spatial and temporal resolution, accelerated and expanded research into application of probabilistic forecasting, network infrastructure research aimed at security and SOA, managing variability in en route airspace, terminal airspace, and ground demand and capacity, and control safety risks better.

7.2 Research Challenges

Weather science and technology are needed to enable transformations in the Weather Concept Operating Principles defined in the *NextGen Weather ConOps*[7] and further clarified in the *NextGen IWP*[8] and comprise the five categories below.

- ***Enhanced forecasting models/techniques, sensors, and DSTs***
  It must be emphasized from the outset that according to the *NextGen Weather ConOps*, research in forecast accuracy improvement is only one component of the fundamental science need to get NextGen operational. NextGen will need the spatial and temporal resolution of weather information to meet operational requirements, and it will need enhanced sensor capabilities. Ongoing development of sensors to enhance and expand ground, airborne, and space-based weather sensors will continue beyond Final Operational Capability (FOC). However, these enhancements must primarily serve the need for probabilistic weather information. It is expected that probabilistic weather information will be integrated into DSTs by Mid-Term Operational Capability (MOC).

- ***Improved understanding of the optimum roles of human forecasters and automation***
  Efforts to design efficient DSTs, reduce controller workload, and enhance NAS safety will change the role of human forecasters in NextGen. The amount of weather information and weather products will dramatically increase. Information use will also transition from human-in-the-loop to human-over-the loop. It is expected that weather information products, dissemination, and integration in DSTs will become partially automated by MOC and largely automated by FOC. The human performance implications of a changing operational environment must be assessed by IOC before automation can be appropriately designed.

- ***Data collection for, access to, and population of the 4-D Wx SAS***
  As described in Chapter 3, it is expected that net-enabled weather observations and forecasts, as well as the structure to manage the development, authorization, standards, policy, and certification of the 4-D Wx Data Cube to source the 4-D Wx SAS will be available by IOC. Development of the 4-D Wx SAS is foundational to the integration of weather with ATM DSTs for common situational awareness.

[7] NextGen Weather Concept of Operations, Version 1.0, May 13, 2006, www.jpdo.gov
[8] NextGen Integrated Work Plan (IWP), www.jpe.jpdo.gov

- ***Techniques to integrate and tailor weather information into ATM decision making and procedures***
  As described in Chapter 4 of the Plan, by IOC, some weather information will flow through a translation process to enable integration into DSTs. Some initial implementations of M2M ATM-Weather integrated DSTs are expected by MOC. It is intended that weather information will be translated to threshold events or NAS constraints and ingested into most DSTs by FOC. Weather information is expected to support more advanced flexible airspace and TBO by FOC.

- ***Enhanced Aircraft Capabilities***
  It is expected that NextGen will enable aircraft to participate more fully in the observation network and receive information tailored to performance-based procedures, such as turbulence, wake, or icing data by MOC. It is expected that NextGen will use adaptive controls to direct observation sensors on aircraft and satellites in real time by FOC.

The NextGen functional area "Weather Information Services" requires research and development (R&D) activities that will guide the implementation of Weather Information Services OIs and Enablers (EN) within the *NextGen IWP*. These R&D activities describe the basic or applied research programs and the results needed to support other NextGen planning elements which enable transformations in NextGen's functional areas derived from the *NextGen EA* and *NextGen ConOps*.

There are over 200 NextGen R&D activities identified in the *NextGen IWP*. Table 7-1 (following page) shows the planned evolution of the R&D activities needed to support the Weather Information Services functional area for NextGen. Although these activities are explicitly weather related, weather information and weather information services play a strong role in many of the remaining NextGen R&D activities not listed in the table. Examples include applied research on Low-Visibility and Surface Operation Technologies (R-0120), Effective Surface Management in Various Weather Conditions (R-0630), Flight Risk Assessment Algorithms (R-1170), and Human Performance Models (R-2121). The research and development requirements highlighted for 2010 completions are on schedule and will meet the needs of IOC.

By 2011, research in the roles of human forecasters and automation systems, climate change impacts, weather integration into decision making, and resolution improvements in weather sensing and forecasting must be completed. Additionally, development in adaptive weather observing, forecaster operating procedures, and climate change impact assessments must be accomplished.

By 2012, research on an initial set of probabilistic weather forecasts must be completed and development on wake vortex tools and procedures must be accomplished.

By 2013, research on aircraft-to-aircraft hazard information exchange and lightning systems must be completed. Development of a forecast verification system and forecast models for the 4-D Wx Data Cube must also be accomplished.

R&D Name	FY10	FY11	FY12	FY13	FY14	FY15	FY16
R-0100 Accuracy / Resolution Requirements for Weather Forecasts	◇						
R-0110 Integration of Forecast and Observational Data	◇						
R-0580 Initial Probabilistic Weather Forecasts			◇				
R-0600 Assessing and Predicting Wake Severity							◇
R-8060 Hazard Information Exchange using Aircraft Sensor Technology				◇			
R-1230 Weather and Wake Impacts for En Route Operations						◇	
R-1520 Role of Human Forecasters and Automated Systems		◇					
R-1760 Methodologies and Metrics to Assess Climate Change Impacts		◇					
R-2112 Weather Integration into NextGen Decision Making		◇					
R-2114 Improved Weather Sensing and Forecasting Models		◇					
D-0320 Adaptive Weather Observation Capabilities		◇					
D-0840 Weather Forecast Assessment Verification System				◇			
D-0850 Network-Enabled Weather Information System						◇	
D-1220 Development of Weather Hazard Severity Indices						◇	
D-1530 Spatial Weather Prediction Models for the 4-D Wx Data Cube				◇			
D-1640 Wind-Dependent Wake Vortex Arrival Procedures and Tools			◇				
D-1680 Advanced Wake Sensing Capabilities						◇	
D-2113 Operating Procedures for Human Forecasters using Automated Systems		◇					
D-2115 Initial Probabilistic Weather Forecasts	◇						
D-2117 Network-Enabled Weather Data Standards	◇						
D-2123 Aircraft Systems Weather Mitigation Requirements							◇
D-2141 Methodologies/Metrics to Assess Aviation's Impact on Climate Change		◇					
D-2193 Enhanced Space-Based Weather Sensors	◇						

Table 7-1 Weather Information Services R&D Activities Timetable

7.3 NextGen Oriented Agency Activities

The development of NextGen capabilities that enable situational awareness and seamless global operations is presenting opportunities to align weather research within the FAA's AWRP, NOAA's operations (NWS) and research (Office of Oceanic and Atmospheric Research), and NASA's Applied Sciences Weather Program to meet long-term requirements for NextGen.

7.3.1 FAA

The FAA's AWRP addresses specific requirements for weather-related support to aviation. They work with the FAA's Weather Requirements Division to base its direction and efforts on the operational problems that need to be solved. Several meteorological product development teams comprise the AWRP, each targeting specific prioritized operational weather problems. Each team develops detailed seven-year work plans that include collaboration with other

agencies. AWRP contributes to achieving NextGen goals by providing research that addresses needs identified in the *NextGen IWP*.

AWRP research products are evaluated through the NextGen Weather Evaluation Capability (NWEC) process, which maps the science to mission needs, enterprise architecture, functional and performance goals, budget and resource requirements, risk mitigation, and schedule. The AWRP is also a critical component of the FAA's research-to-operations (RTO) process that transitions the science achieved through research into technologies deployed for operations.

AWRP is sponsoring research that will address the development of timely and accurate deterministic (and an initial set of probabilistic) aviation weather forecasts for operational use in ATM by 2012. By 2016, they expect development in improved accuracy of deterministic forecasts and an expanded set of probabilistic aviation weather forecasts for operational use. By 2020, advanced improvements in the accuracy of these weather forecasts are expected to be available for NextGen. Their current research areas include convective weather, turbulence, in-flight icing, national ceiling and visibility, volcanic ash, forecast model developments and enhancements, advances in weather radar techniques, and quality assessment.

7.3.2 NOAA

NOAA's operations (NWS) and research (Office of Oceanic and Atmospheric Research [OAR]) is the primary R&D organization with NOAA. Weather and air quality is a major research area addressed by OAR. OAR is addressing NextGen Science and Technology (S&T) needs with a science-service focus on aviation weather research, and with foci on enabling capabilities in observations, modeling, post-processing of weather information, and forecaster applications research. The NWS and OAR are increasing coordination in DSTs. Currently, OAR research at Earth Systems Research Laboratory (ESRL) and at the National Severe Storms Laboratory (NSSL), and partnered with the FAA, is aimed at technologies for meteorologists-over-the-loop, at the 4-D Wx SAS, and at communicating forecast uncertainty. It is expected that NextGen enabling capabilities will provide broader benefits to NOAA that will improve access to all NWS products and services via the 4-D Wx Data Cube, enhance IT and data management, and extend AWIPS enterprise services into a system-of-systems that links AWIPS[9] to MADIS[10], NDFD[11], CCS[12], and NEXRAD[13].

NOAA's strategy is to build a little and test a little by field forecasters in a simulated operational environment. NOAA test beds (i.e., Hurricane, Climate, Development Testbed Center, Hydro-meteorological, Aviation Weather Center, and Hazardous Weather) and an Operational Proving Ground will be built on AWIPS II and NextGen architecture to provide common software development platforms that enable interagency collaboration and data sharing.

[9] Advanced Weather Interactive Processing System (AWIPS)
[10] Meteorological Assimilation Data Ingest System (MADIS)
[11] National Digital Forecast Database (NDFD)
[12] Central Computing System (CCS) at National Centers for Environmental Prediction (NCEP)
[13] Next Generation Radar (NEXRAD)

NOAA is developing a five-year Research Plan, which includes milestones for it's research aimed at improving products and information services in the near term, and a 20-year Research Vision for the agency, which adopts a longer-term perspective. They have planed for research to provide accurate, timely, and integrated weather information to meet air and surface transportation needs. Within the next two years, work is planned to develop standards and protocols for weather-related electronic data exchange and network-related operations, and to validate methodologies for acquisition, processing, and dissemination of weather-related data. For their 3-5 year milestones, they have planned to transition research weather-observation prototypes into full operational use, to enable private sector partners to market acquired tools and expertise, to prototype an aviation database concept with weather elements, and to quantify human forecaster value-added contributions.

7.3.3 NASA

NASA's Applied Sciences Weather Program (ASWP) works across the nine societal benefit areas identified by the international Group on Earth Observations (GEO). Research in each of these areas is conducted primarily through open solicitation of proposals for applied research topics of high national priority. This is done through the NASA Research Opportunities in Space and Earth Sciences (ROSES) solicitation program. Most years, the Applied Science Program's Weather element typically selects from two to five research proposals for funding. This research is then implemented, monitored, coordinated, and transitioned to operations through the Weather Element's Advanced Satellite Aviation-weather Products (ASAP) Project. ASAP resides at the NASA Langley Research Center.

NASA ASWP research priorities are primarily developed through close collaboration with the AJP-68, the NOAA NWS Aviation Services branch, the DOD, and others in a collective effort to support the development of NextGen. This is done through direct participation in the NextGen Weather Working Group Environmental Information Team and Weather Demonstration Teams, and in the NextGen Environmental Working Group Science Steering Committee, as well as significant participation in the FAA Aviation Climate Change Research Initiative (ACCRI). The Weather Element also actively supports the Office of the Federal Coordinator for Meteorology (OFCM) Volcanic Ash Working Group and the OFCM Space Weather Working Group. All of these affiliations inform NASA's research priorities.

The NASA ASWP conducts an annual review meeting each year to assess the progress of active research projects as well as their efficacy and applicability to NextGen. Particular emphasis is placed on the active participation of interagency partners and various research and operational centers of excellence (e.g. FAA AWRP, NOAA National Environmental Satellite Data and Information Service [NESDIS], Massachusetts Institute of Technology Lincoln Laboratories, etc.). The review also allows the program to identify research topics for upcoming ROSES solicitations and ASAP tasks. It also ensures that the program's work is aligned with NextGen priorities and the related efforts of our Federal partners. Particular emphasis is placed on identifying research where NASA is uniquely capable of providing data and/or research expertise.

7.3.4 DOD

The DOD is actively engaged in scientific research through a number of agencies. The U.S. Army Research Lab (ARL), the U.S. Navy Fleet Numeric Meteorology and Oceanographic Center (FNMOC) and Naval Postgraduate School, and U.S. Army Research Lab (ARL) are responsible for scientific research related to meteorological issues. Within the U.S. Air Force, basic scientific research is largely coordinated through the Air Force Office of Scientific Research (AFOSR) and performed within the Air Force Research Laboratory (AFRL). About 75 percent of the research is conducted in academia and industry, the remaining 25 percent within the AFRL. Research into weather and aviation impacts primarily takes place within the U.S. Air Force.

The organization with primary responsibility for research pertinent to aviation interests is the 16th Weather Squadron (16WS). Other offices within the Air Force Weather Agency (AFWA) are involved in contracting for, or managing, weather research programs. The responsibility for weather research activities falls to the AFWA/CC and to 16WS. Current research efforts within AFWA with implication to global aviation weather support include researching enhancements for AFWA's dust products, AFWA's contributions to the community Weather Research and Forecasting (WRF) model, and research into the utility of model ensembles to produce probabilistic forecasts. Additional research within AFWA involves the determination of cloud optical properties, improvements in the global cloud analysis product, the development of algorithms to produce operational products using current and planned satellite data, and with space weather. Within the timeframe of NextGen, AFWA will be working on the development of a coupled modeling system, and involved in the planning for the next generation polar orbiting meteorological satellite system.

7.4 Gaps in NextGen Weather Concept S&T

To identify gaps in research using a joint agency approach, we must first identify the research challenges posed by the N*extGen Weather ConOps* and by the *NextGen IWP*. The next step is to match Agency activities that are oriented toward addressing these challenges. The final step is to identify gaps that Agencies must further investigate during refinement of the *NextGen IWP*.

The following initial assessment is in the context of the five basic categories of NextGen Weather research. Although it is clear that the FAA's AWRP, NOAA's OAR, and NASA's broadly challenged ASWP are collaboratively addressing probabilistic forecasting research, some human factors research, and other research to achieve a 4-D Wx SAS, little attention has been given to the ultimate application of weather information services in NextGen – the integration of weather information and services with ATM decision-making capabilities. There is not enough research activity devoted to equipping piloted aircraft and Aerial Systems (UAS) with weather sensors, enabling aircraft to share weather information, and integrating weather into airborne decision support systems. The challenge is in managing interagency research targeted

for NOAA and FAA operations that will benefit NextGen. A summary list of these gaps is given below:

- Probabilistic forecasting
- Human factors
- A 4-D Wx SAS
- Integration of weather information and services with ATM decision-making capabilities
- Enabling piloted aircraft and Unmanned Aerial Systems (UAS) with weather sensing
- Weather information sharing
- Weather integration with airborne decision support systems

Much more work is needed for the look ahead. Agency research priorities have not yet been aligned with all of the S&T needed to achieve the NextGen concept on schedule. From an Agency synchronization perspective, critical areas of research that are being overlooked or un-prioritized such as ATM-Weather Integration and aircraft capabilities point to a need for a national S&T planning process to produce a National Aviation Weather Research Plan. We must carefully decide research directions and agency investments.

To coordinate interagency research activities to meet NextGen weather science and technology development milestones, FAA and NASA have established a research resource allocation process. NOAA research emphasis will be initiated in FY 2011. This process will help to establish the current and near-term maturity levels of NextGen Weather Information Services technology, identify gaps in meeting NextGen user needs, and planning the transition of new technology to operations. Annual reviews of prior year activities, planned activities, and gaps are being planned now. Once that is done, the scientific capacity needed to achieve planned activities must be projected. Required funding will have to be calculated, obtained, or redirected to support needed scientific capacities. Additionally a plan for advocating the roadmap's needs to agency leaders will have to be developed and executed.

The benefits of meeting all of these challenges extend beyond the needs of NextGen weather. NextGen R&D will create broad-based comprehensive models to assess NAS impacts and risks and enhance safety and efficiency for NAS users and NAS operators using conventional and newly developed technologies that are affordable. R&D will develop innovative technologies to reduce weather impact on operations for improved operations efficiency and find ways to improve strategies for CDM systems. R&D will develop better methods to protect the environment and to diminish the rate of long-term global climate change. R&D will give us a better understanding of how weather affects the economic return to the aviation industry. With a better understanding of the aviation industry's economic sensitivity to weather, NextGen's

enhanced capabilities for the NAS will be tailored to stimulate entrepreneurship and business development.

Subsequent versions of the NextGen weather science and technology roadmap must establish a relationship for NextGen Weather research goals with FAA, NOAA, and NASA research goals. The JPDO Weather Working Group advocates activities that are scientifically sound, relevant, and responsive to stakeholder needs, and asks that research managers use analytical assessments to conduct performance planning in order to translate important issues and problems into priorities for resource allocations. Throughout the process, we need to assess where the science is going, what the active scientific research community thinks will be feasible, and what is beyond its reach.

8 NEXTGEN WEATHER GLOBAL HARMONIZATION

8.1 Global Harmonization

The goal of NextGen Weather Global Harmonization efforts is to facilitate the key global interoperability between NextGen and major air transportation programs around the world, for example SESAR, developed by the European Community (EC), the Comprehensive Assessment and Restructure of the Air Traffic Services (CARATS), developed in Japan, and China's Next Generation Air Transportation System (CNATS). The establishment of operational standards and multilateral agreements to coordinate planning and implementation of NextGen weather-related transformations in technology and procedures for the delivery of the common weather picture accomplish this. Consistency and focus is key. That means sharing flight plans, developing common procedures, and systems that allow for the seamless movement of flights into other countries' airspace.

Most of the present work has been in collaboration with the European Community. The starting point for integrating NextGen and SESAR came in the form of a Memorandum of Understanding (MOU) with the EC in 2006, which builds on the foundation started with long-term cooperation with EUROCONTROL. This MOU was a clear statement of intent by both Europe and the U.S. to harmonize our ATM systems of the future[14].

Global Harmonization is a key NextGen characteristic identified in the *NextGen ConOps*. According to the *NextGen ConOps*, the ATM system is globally harmonized through collaborative development and implementation of identified best practices in both standards and procedures. There are several differences and similarities between the U.S. and Europe that identify gaps and opportunities for harmonization.[15] An area of difference between the NextGen and SESAR ConOps is how weather is considered in the two concepts. In the U.S. NAS, summer convective weather causes a majority of system-wide delays and therefore has been included as a core element of the proposed concept. Weather is recognized in the SESAR ATM Target Concept, but there does not appear to be the same level of focus on infrastructure, prediction, modeling, and planning as appears to be included in the NextGen concept.

There are many distinctions between the U.S. and Europe that present challenges to harmonization. General Aviation (GA) markets are different. Weather severity, Visual Meteorological Conditions (VMC), and Instrument Meteorological Conditions (IMC) are defined differently. Traffic volumes are different and there is diversity of language and cultures. ATM services are different in number and governance of service providers, and their sources of finance are different. ATM system uniformity/fragmentation is different. ATM system automation capability, age, and procurement rules are different. Domestic preferences in ATM

[14] ICAO NextGen/SESAR Integration Forum, "In Perfect Harmony". Mr. Robert A. Sturgell, Acting Administrator, Federal Aviation Administration Integration and Harmonization of NextGen and SESAR into a Global ATM Framework, ICAO HQ, Montreal, Canada, 8-10 September 2008

[15] JPDO Paper, A Comparative Assessment of the NextGen and SESAR Operational Concepts, Paper No: 08-001, May 22, 2008, JPDO Global Harmonization Working Group

Systems are different. The delegation of separation and conflict avoidance is different. Data links are different (1090ES vs. UAT vs. VDL4). RNP/RNAV requirements are also different.

There are, however, similarities between the U.S. and Europe that can be addressed to begin harmonization. There is the same pressure to maintain safety, accommodate growth by increasing capacity and efficiency, eliminate restrictions, and contain costs. Both the U.S. and Europe work with the same types of aircraft, airlines, avionics, and pilots, and both adhere to the same obligations (i.e., Chicago Convention, and ICAO SARPS). Both are trying to move forward under the same constraints such as political visibility, environmental pressures, financial constraints, and security demands, and both are looking for high technical & operational competence and advanced technology.

Weather information sharing and ATM-Weather Integration are broad targets for NextGen & SESAR cooperation to ensure that the same aircraft can fly in both systems, to ensure common standards, to minimize costs by sharing results and efforts, and to enable manufacturers to compete and supply both markets. NextGen and SESAR systems cannot be completely identical but they must be aligned, making transatlantic cooperation essential. Sharing developments is an important first step in the globalization process. This can identify commonalities between the weather systems, as well as differences, and it can highlight how the weather harmonization and interoperability efforts that have been made will benefit ANSPs, users and stakeholders. Weather harmonization activity, such as participation in the development of Global Weather Standards will move toward global interoperability and consistent implementation of weather systems, and achieve seamlessness and interoperability with common aeronautical information exchange models.

8.2 International Strategy

The JPDO Global Harmonization Working Group strategy is to harmonize equipment and operations globally.[16] Collaborative development of ICAO strategic documents has helped to provide a common framework to guide planning and implementation of CNS/ATM systems, to identify weather-relevant global air navigation initiatives and to reduce the rate of weather-related fatal accidents in air transport operations. These documents include the *Global ATM Operational Concept*, the *Global Air Navigation Plan*, and the *Global Aviation Safety Plan*.

8.2.1 ICAO Global ATM Operational Concept[17]

Nation States, regional planning groups and the aviation industry are requested to focus all such development work on the ICAO *Global ATM Operational Concept*. Under this Concept, aircraft are to be separated from other aircraft, terrain, and incompatible airspace activity, and from surface vehicles and other obstructions on the apron and maneuvering area. This concept includes the provision of meteorological information as an integrated function of the ATM

[16] JPDO Paper No: 09-013, January 7, 2010, Next Generation Air Transportation System International Strategy
[17] Global ATM Operational Concept, Doc 9854, AN/458, First Edition, ICAO, 2005

system, and tailors this information to meet ATM requirements in terms of content, format, and timeliness.

8.2.2 ICAO Global Air Navigation Plan[18]

Five of the nearly two-dozen *Global Air Navigation Plan* initiatives address weather. These include Situational Awareness, Aerodrome Design and Management, Runway Operations, Match IMC and VMC Operating Capacity, and Meteorological Systems.

The objectives of the Situational Awareness initiative are to operationally implement data link-based surveillance, to implement equipment that allows traffic information to be displayed in aircraft which will support conflict prediction and collaboration between the flight crew and the ATM system, and to improve situational awareness in the cockpit by making available the electronic terrain and obstacle data of required quality. The Implementation of surveillance systems which track aerodrome surface movement that is constrained by weather conditions and capacity will also enhance safety and efficiency. The implementation of cockpit displays of traffic information (CDTI) and associated procedures will enable pilots to participate in the ATM system and improve safety through greater situational awareness.

The objective of the Aerodrome Design and Management initiative is the implementation of management and design strategies to improve aircraft movement within the terminal area. The ATM system should enable the efficient use of the capacity of the aerodrome airside infrastructure to ensure the ability to safely maneuver in all weather conditions while maintaining capacity.

The objective of the Runway Operations initiative is to maximize runway capacity. Enhancing the performance of runway operations begins with the establishment of runway capacity benchmarks, which are usually defined as the maximum number of flights an aerodrome can routinely handle in an hour for above Category I weather minimum. Where warranted, it should be an objective to utilize aircraft capabilities and available runways in the most appropriate manner to move the all weather throughput as close to the visual throughput as possible. Runway capacity constraints are partially defined by weather limitations.

The objective of the Match IMC and VMC Operating Capacity initiative is to improve the ability of aircraft to maneuver on the aerodrome surface in adverse weather conditions. According to the referenced document, implementation of Advanced Surface Movement Guidance & Control System (A-SMGCS), DSTs, and associated procedures offer the best solution for aircraft to operate in all weather conditions. Synthetic vision, based on detailed aerodrome map, can enhance situational awareness under adverse weather conditions where runway/taxiway markings may be obscured. Controllers should also have access to systems to help them develop and maintain situational awareness of all traffic on the movement area in all weather conditions.

[18] Global Air Navigation Plan, Doc 9750, AN/963, Third Edition, ICAO, 2007

The objective of the Meteorological Systems initiative is to improve the availability of meteorological information in support of a seamless global ATM system. Immediate access to real-time, globally operational meteorological (OPMET) information is required to assist ATM in tactical decision-making for aircraft surveillance, ATFM and flexible/dynamic aircraft routing which will contribute to the optimization of the use of airspace. Such stringent requirements will imply that most meteorological systems should be automated and that meteorological service for international air navigation be provided in an integrated and comprehensive manner through global systems such as the World Area Forecast System (WAFS), the International Airways Volcano Watch (IAVW) and the ICAO tropical cyclone warning system. Enhancements to WAFS, IAVW and the ICAO tropical cyclone warning system to improve the accuracy, timeliness and usefulness of the forecasts issued will be required to facilitate the optimization of the use of airspace. Increasing use of data-link to downlink and uplink meteorological information (through such systems as D-ATIS and D-VOLMET) will assist in the automatic sequencing of aircraft on approach and will contribute to the maximization of capacity. Developments of automated ground-based meteorological systems in support of operations in the terminal area will provide OPMET information, (such as automated low-level wind shear alerts) and automated runway wake vortex reports. OPMET information from the automated systems will also assist in the timely provision of forecasts and warnings of hazardous weather phenomena. These forecasts and warnings, together with automated OPMET information, will contribute to maximizing runway capacity.

8.2.3 ICAO Global Aviation Safety Plan (GASP)[19]

This plan stresses the need for a reduction in the rate of fatal accidents in air transport operations. GASP encourages Nation States to foster regional and sub regional safety groups for the purpose of furthering the global safety effort. Weather is considered one of a few top accident categories that should be regionally addressed. Conferences on GASP stressed the need for greater transparency and sharing of safety-related information, including weather information, among ICAO Member Nation States and air transport industry stakeholders as the basis for a new global strategy to significantly improve aviation safety around the world.

GASP also addresses Performance Based Navigation (PBN), which defines performance requirements for aircraft navigating on an Air Traffic Services (ATS) route, terminal procedure or in a designated airspace. Through the application of RNAV/RNP specifications, PBN provides the means for flexible routes and terminal procedures. The safety improvement offered by PBN is that it reduces diversions caused by adverse weather conditions. This in turn enhances the capacity and efficiency of aerodrome operations to allow aircraft to safely maneuver in all weather conditions.

Automated weather situational awareness can also reduce weather-related safety risk. In some regions, pilots have to depend on the area controller for weather information and as there is only one controller on shift, hence, sometimes due to traffic congestion, it is not possible for the duty controller to pass weather information in time.

[19] Global Aviation Safety Plan, ICAO, 2007

8.2.4 FAA Air Traffic Organization International Strategic Plan

The FAA *ATO International Strategic Plan, FY 2010*, which is used to manage the ATO's international strategic activities, has been updated to include weather. Specifically, the ATO International Office has the responsibility to collaborate across ATO Service and Business Units on the development and maintenance of a unified international strategic focus to effectively address global, regional, and cross-boundary plans, as well as activities and policies, including ATM, meteorological services, safety, security and the environment.

8.3 Global Harmonization of Operations

Global harmonization of operations impacted by weather must address oceanic TBO, cross-polar routes, communications, the World Area Forecast System, volcanic ash, and more.

8.3.1 Oceanic TBO

To support oceanic TBO, surface movement based on Airport Surface Detection Equipment – Model X (ASDE-X) can be optimized while accommodating changes in airport operations due to weather and wind direction. To support CDA via Oceanic Tailored Arrivals and Optimized RNAV Star programs, consistent weather information on both ends of the trajectory is necessary for planning. Pre-Departure and In-Flight Oceanic Trajectory Management 4-D (OTM4D) will include procedures and automation to identify opportunities for flights to fly more efficient profiles based on real-time evaluation of weather impacted airspace availability.

8.3.2 Cross-Polar Routes

The Cross Polar Trans East Working Group, an ad hoc group of U.S., Canadian, and Russian air traffic controllers, airline dispatchers, and operations managers can facilitate the process of defining user requirements. Aviation operators confirm that the polar routes reduce both travel time and operating costs. If polar routes are not available, the additional operating costs and penalties for an unscheduled stop or reroute can total hundreds of thousands of dollars per flight. Very little information is available on how much space weather is responsible for delays or reroutes on polar routes, therefore internationally collaborative research is needed.

8.3.3 Communications

Weather Information will be exchanged using a family of platform (technology) independent, harmonized and interoperable information exchange models designed to cover the information needs of ATM. Three tiered data models together provide conceptual, structural and physical representations of weather data. These data models promise to aid in harmonization of weather data exchange between air traffic control systems in the US and Europe. The first, or Weather Conceptual Model (WXCM) provides a high-level, implementation-independent look at how weather data concepts are connected. The second, or Weather Exchange Model (WXXM), provides a more logical and structural (if still implementation-independent) perspective of the

same data, in more complete detail — the interrelationships of every weather data concept are spelled out. The third, or Weather Exchange Schema (WXXS) is a machine-generated, XML-formatted implementation of the Exchange Model — a "physical" code version of it. Work is underway to collaboratively develop international standards that will meet the needs of both NextGen and SESAR.

8.3.4 World Area Forecast System

The responsibility of providing AIS is usually delegated to Nation State-owned or controlled AIS offices/organizations. These are often run by the local ANSPs. Military operate their own AIS offices/organizations. AIS Manager Meteorological data originate at meteorological authorities (World and Regional Area Forecast Centers [WAFC, RAFC]) and are distributed among those using dedicated networks. They are made available to the aeronautical meteorological offices. WAFS is a program developed by the ICAO and the World Meteorological Organization (WMO) to improve the quality and consistency of en route guidance provided for international aircraft operations.

Changes in meteorological services that relate to the NextGen and SESAR projects within the US and Europe respectively will result in major changes to the way air traffic is managed, particularly with respect to the WAFS Program. The requirement for the 4-D Wx Data Cube concept and for a 4-D Wx SAS concept may, in future years, lead to a consolidation in the activities of the WAFCs. WAFS access to and use of shared global gridded fields for icing, turbulence, convection, wind, temperature, and humidity data can be considered as the first step towards these concepts. In the future, U.S. FAA NextGen and EuroControl SESAR Programs will profoundly impact the issuance and distribution of all OPMET information, including the representation and coding of WAFS forecasts. The influence of the 4-D Wx Data Cube and 4-D Wx SAS concepts, together with the need to harmonize the OPMET information with the AIS data for flight planning purposes, may be expected to be substantial and will have to be assessed from the WAFS point of view.

There is interest within the World Area Forecast Systems Operations Group, which guides WAFC Provider Nation States in meeting current global and regional WAFS operational requirements, in preparing an assessment of the expected impact of the NextGen/SESAR programs on the future of WAFS, and in developing a migration plan to take account of these 4-D Wx Data Cube and 4-D Wx SAS capabilities. The ICAO, in concert with the WMO and National Meteorological Service Providers, works with the ATM community and its stakeholders to determine user requirements for changes to current and/or the addition of new products and services.

New WAFC terminal forecasts will be produced in a digital, gridded format, initially being available as a Web-based graphic in the 2013 time frame. At this time, the product will include forecasts of convection, winds, low ceiling and visibility, and winter weather. By 2018, other elements important to aviation and the environment will be included, such as icing, turbulence, wake vortices, noise abatement, and air quality. In addition, probabilistic attributes of the various weather elements will be included. The new terminal forecast will be a critical

component to ongoing worldwide activities to develop future ATM systems, such as NextGen and SESAR activities in the USA and Europe, respectively. These future ATM systems will integrate weather information with aircraft and other operational information to provide pilots, dispatchers and controllers with a common operating picture that will increase efficiency and, at the same time, reduce the impact of aviation on the environment. A pilot's ability to receive the weather information, in both textual and graphical format, directly in the cockpit by uplink will be particularly crucial in achieving this.

8.3.5 Volcanic Ash

Due to the extreme vulnerability of aircraft to volcanic ash, NextGen has a continuing requirement for the detection and forecasting of ash clouds for incorporation into the 4-D Wx Data Cube to drive the air traffic flight planning and management process. Efforts are underway to define and validate the specific requirements of the 4-D Wx Data Cube for volcanic ash observations and forecasts, develop a plan for a 2016 capability that will meet as many of the requirements as are feasible, and to work with the community of users to argue the funding of this effort within NextGen budgets.[20]

Volcanic Ash Advisory Centers (VAAC), established by the ICAO, disseminate information globally about volcanic eruptions, the presence of ash in the atmosphere and forecasts of the dispersion of the ash. The VAAC's are part of an international system called the International Airways Volcano Watch (IAVW). The IAVW comprises observations of volcanic ash from volcano observatories and other organizations, satellites and aircraft in flight, the issuance of warnings (e.g., Notices to Airmen [NOTAM] and Significant Meteorological Information [SIGMET] messages) and the issue of volcanic ash advisory messages from the VAACs identifying areas of volcanic ash and their predicted movement. Eight countries have contracted with ICAO to establish and run VAACs. These are located in London, England; Toulouse, France; Montreal, Canada; Darwin, Australia; Wellington, New Zealand; Tokyo, Japan; and Buenos Aires, Brazil. In the United States, NOAA runs VAACs in Anchorage, Alaska, and Washington, D.C.[21]

A global harmonization of systems is needed to manage a volcanic ash event much like a major weather event. Aviation operations in volcanic ash situations rely on timely and accurate information based on detection and monitoring, alerting, modeling, and post-event assessments. This requires access to global seismic monitoring networks to provide early warnings when an eruption is imminent or has occurred, which is especially important for en route aircraft. It also requires global satellite monitoring as a core element in detection, tracking, and monitoring eruptions, and the resultant ash plume. Pilots also make observations, and these are shared via pilot reports or AIREPs and may be included in NOTAMs and SIGMETs. The prediction of volcanic ash cloud dispersion is based on weather modeling. Because different approaches to

[20] RAL Strategic Plan 2009-2013
[21] Statements of Victoria Cox, Senior Vice-President for NextGen and Operations Planning, Before the U.S. House of Representatives Committee on Science and Technology, Subcommittee on Space and Aeronautics on Mitigating the Impact of Volcanic Ash Clouds on Aviation – What Do We Need To Know? May 5, 2010

modeling are used by the various VAACs, processes to harmonize diverse ATM guidance must be established. Post assessments of the various VAAC-issued guidance are needed to determine how best to improve the services provided to industry and to ATM.

Volcanic ash constrains airspace and requires coordinated action by multiple civil aviation authorities. In the NextGen era, regulators must manage volcanic ash across Nation State boundaries. Agencies can share operator avoidance practices and identify operational solutions for reopening airspace by developing a collaborative volcanic ash forecasting process and considering "pathfinder" test flight traffic patterns between cities with a low ash impact. NextGen will enable an improved information sharing process. NextGen focuses on how best to put information into a format that can be used by pilots, controllers, and dispatchers/flight followers and integrated into DSTs or systems. Volcanic ash information is treated like other hazardous weather information. Network enabled weather information integrated into ATM DSTs will help improve the quality and timely delivery of information to global airspace users, enabling all users to make more informed operational decisions when confronted with adverse conditions such as volcanic ash.

8.3.6 More to Do

Current Standards and Recommended Practices (SARP) and Procedures for Air Navigation Services (PANS) need to be assessed to determine the degree to which they support the migration to the Global Concept. These standards improve the efficiency of operations and seamless transfer of information. Meteorological data is a key component of this service need. Situations in which national practices in NextGen may not accommodate international service requirements must be minimized.

APPENDIX A. LIST OF ANNEXES

ANNEX 1. NextGen Four-Dimensional Weather Data Cube Plan

ANNEX 2. NextGen ATM-Weather Integration Plan

ANNEX 3. NextGen Weather Demonstration Inventory

ANNEX 4. NextGen Weather Research & Development Plan

APPENDIX B. ACRONYMS

AIM	Aeronautical Information Management
AMOFSG	Aerodrome Meteorological Observation and Forecast Study Group
ANSP	Air Navigation Service Provider
ASDE-X	Airport Surface Detection Equipment – Model X
A-SMGCS	Advanced Surface Movement Guidance and Control System
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATO	FAA Air Traffic Operations
ATS	Air Traffic Services
AWIPS	Advanced Weather Interactive Processing System
AWRP	Aviation Weather Research Program
CATM	Collaborative Air Traffic Management
CARATS	Comprehensive Assessment and Restructure of the Air Traffic Services
CBO	Congressional Budget Office
CDM	Collaborative Decision Making
CNS	Communication Navigation Systems
ConOps	Concept of Operations
CTOP	Collaborative Trajectory Options Program
DOC	Department of Commerce
DOD	Department of Defense
DST	Decision Support Tools
EC	European Community
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FIR	Flight Information Region
Flex	Flexible Terminal and Airports
FOC	Final Operational Capability
FOC	Flight Operations Center
FTI	Federal Telecommunications Infrastructure
GASP	Global Aviation Safety Program
GEOSS	Global Earth Observation System of Systems
GNSS	Global Navigation Satellite System
HD	High Density Airports
IAVW	International Airways Volcano Watch
ICAO	International Civil Aviation Organization
IM&S	Information Management and Storage
IOC	Initial Operating/Operational Capability
IMC	Instrument Meteorological Conditions
IT	Information technology
IWP	Integrated Work Plan
JMBL	Joint METOC Broker Language
JPDO	Joint Planning Development Office
MOC	Mid Operational Capability

MOU	Memorandum of Understanding
M2M	Machine-to-Machine
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NCO	Net-Centric Operations
NEO	Networked-Enabled Operations
NEVS	Network-Enabled Verification Service
NEWP	NextGen Executive Weather Panel
NextGen	Next Generation Air Transportation Management System
NGIP	FAA's NextGen Implementation Plan
NNEW	NextGen Network Enabled Weather
NOAA	National Oceanic and Atmospheric Administration
NOAAnet	NOAA Network
NWIS	NextGen Weather Information Services Plan
NWP	NextGen Weather Processor
NWS	National Weather Service
OCONUS	Outside Continental United States
OGC	Open Geospatial Consortium
OI	Operational Improvements
OMB	Office of Management and Budget
OPD	Optimized Profile Descents
OPMET	Operational meteorological
OSTP	White House Office of Science and Technology Policy
OTM4D	Oceanic Trajectory Management 4-D
PANS	Procedures for Air Navigation Services
PBN	Performance Based Navigation
POC	Point of Contact
REDAC	FAA's Research, Engineering, and Development Advisory Committee
RNP/RNAV	Required Navigation Performance/Area Navigation
RRIA	Re-route Impact Assessment
RWI	Reduce Weather Impact
R&D	Research and Development
SARPS	Standards and Recommended Practices
SAS	Single Authoritative Source
SESAR	Single European Sky ATM Research
SIGMET	Significant Meteorological Information
SOA	Service-Oriented Architecture
SOP	Standard Operating Procedures
SPC	Senior Policy Committee
SSA	Shared Situational Awareness
SWIM	System Wide Information Management
TBO	Trajectory Based Operations
TFM	Traffic Flow Management
VAAC	Volcanic Ash Advisory Centers
VMC	Visual Meteorological Conditions

WAFS	World Area Forecast System
WAIWG	Weather – Air Traffic Management Integration Working Group
WIFS	WAFS Internet File Server
WIP	ATM-Weather Integration Plan
WMO	World Meteorological Organization
WTIC	Weather Technology in the Cockpit
WXCM	Weather Conceptual Models
WXXM	Weather Exchange Models
WXXS	Weather Exchange Schema
Wx WG	Weather Working Group
4-D	Four Dimensional

APPENDIX C. GLOSSARY

ATM Impact Conversion: Information from Weather Translation converted into potential NAS state changes and/or capacity impact, such as known ATM demand/capacity information, safety key factors, and other constraints (e.g., Special Activity Airspace, runway closures).

ATM Decision Support: Traffic management plans for decision makers produced from ATM decision support tools (DSTs) using results from ATM Impact conversion.

Common Weather Reference: A shared standard source of weather information that orients multiple users to a single representation of the weather state. The common weather reference in NextGen is the 4-D Wx SAS.

Consistent Weather Uncertainty: The development of a single answer to describe the uncertainty in a forecast element when more than one quantification of uncertainty exists. The concept of a consistent weather uncertainty refers to how the SAS will be populated with forecasted weather information with a unique uncertainty at each grid point. This unique uncertainty will have been derived from Cube forecasts each containing different uncertainties. Varied NAS decision makers will be able to make decisions that address weather risk based on consistent or unique weather uncertainty.

Demonstration: Demonstrations refer to new and emerging technologies that will illustrate the ideas, methods, systems, and performance that will enhance the effectiveness of weather observations and forecasts employed to satisfy NextGen's goals. Specifically, demonstrations include (list not all inclusive): weather observations and forecast data into the 4-D Wx Data Cube, weather information integration into ATMS, non-weather systems (e.g., ATMS) that require or will require timely and accurate weather information, and improved weather data and forecasts for all the domains of the NAS (terminal, en route, and oceanic).

Full Operational Capability: FOC is defined uniquely by agency.

F**our-Dimensional:** Time, altitude (e.g., flight level, mean sea level, above ground level, etc.), and horizontal position (e.g., ICAO airfield identifier, latitude and longitude, military grid reference system, NAS hexagonal control grid, etc.).

High-Glance Value: Stand-alone weather displays and products improved for enhanced usability by ATM. These weather displays are upgraded to reduce the amount of interpretation required for rapid understanding of the weather situation. These displays reduce TFM decision-makers' requirement to have a deep understanding of weather situations.

Initial Operational Capability: According to the *NextGen IWP*, Operational Improvements (OI) are assigned an Initial Operational Capability (IOC) date. This date is when the OI initially provides the functions and services described for the entire OI at a specific location. The date does not describe when the OI will be fully deployed at all required locations. The IOC date is

relevant only to the OI's Office of Primary Responsibility (OPR). The IOC date is critically dependent upon timely policy and procedural agreements between OPRs and Offices of Coordinating Responsibility (OCR), and among different stakeholders.

NextGen Weather Enterprise: An effort undertaken that requires boldness and energy which exceeds the scope of a single Agency's acquisition program to deliver all weather-relevant capabilities to NextGen.

Stand-Alone: Stand-alone non-weather systems function completely without weather input. Stand-alone weather systems function independently of other non-weather systems. Generally, weather is interpreted manually with stand-alone tools and displays.

Uncertainty: The uncertainty of a forecast or forecast element is the likelihood of occurrence. Uncertainty is a fundamental characteristic of weather predictions and is generally described in terms of a probability (percentage) that an event will occur. Weather probability is used to describe one possible event due to the impossibility of exactly describing a future outcome; the future outcome is uncertain.

User-in-the-Loop Tools: User-in-the-loop tools ingest constrained area information and apply NAS traffic and other pertinent information (outages, construction, etc.) to determine impact. This impact is then fed to a DST for resolution, which the user can accept, reject, or modify, or manually use to determine the best solution. There is a Human In The Loop (HITL) on the "ATM side" providing oversight of the conversion output and its reliability, oversight of the traffic and facility information, as well as involvement in selection of the proposed solutions. The level of oversight may vary greatly as users gain confidence in these systems.

Virtual Repository: A collection of local, remote, or other virtual repositories, and databases accessible via a single reference location. The 4-D Wx Data Cube is a unique virtual repository of weather information.

W**eather Constraint:** A theoretical reduction in airspace permeability (en route or at the arrival and departure terminals) due to the presence or forecasted presence of weather.

Weather State: The observed, analyzed, and forecasted meteorological parameters associated with the current or future state of the atmosphere.

Weather Translation: Ingest of weather observations, analyses, and forecasts to produce relevant, standardized threshold events and/or characterizations of weather-related national airspace system (NAS) constraints, Federal Aviation Regulations (FARs), Flight standards, Aircraft limitations, Standard operating procedures (SOPs).